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MISSOURI
GEOLOGICAL SURVEY

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MISSOURI

GEOLOGICAL SURVEY

VOLUME IX

REPORTS ON AREAL GEOLOGY

(SHEETS 1-4)

CHARLES R. KEYES

STATE GEOLOGIST

JEFFERSON CITY:
TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS.
1896.

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LETTER OF TRANSMITTAL.

MISSOURI GEOLOGICAL SURVEY,
JEFFERSON CITY, April 2, 1896.

To the President, Governor Wm. J. Stone, and the Members of the Board of Managers of the Bureau of Geology and Mines :

GENTLEMEN—I have the honor to transmit to you herewith, volume IX of the Missouri Geological Survey. It is the first of the series on areal geology and comprises reports and detailed maps of four sheets.

The first, or Higginsville sheet, was printed and the folio edition partialy distributed in 1892. The second and third, the Bevier and Iron Mountain sheets, were printed in 1894, and the folio maps and accompanying octavo reports in pamphlet form partly distributed in the latter part of the same year. Of the fourth, the Mine la Motte sheet, the topographic base for the map was practically completed more than two years ago, though the geological work in the area was not done until towards, the close of the season just passed.

To meet the various demands for the geological maps two editions have been issued, one on light paper and folded so to be attached to the report in octavo size; and the second on heavy plate paper which is retained in folio form. The latter is accompanied also by a brief abstract of the report, and a folio sheet of geological sections.

I have the honor to be,

Your obedient servant,

CHARLES R. KEYES,
State Geologist.

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AREAL GEOLOGY OF MISSOURI.

AREAL GEOLOGY AND ITS RELATIONS TO GENERAL GEOLOGICAL WORK.

BY CHARLES ROLLIN KEYES.

The investigation of the natural resources of a district is the chief practical end of geology. Upon this foundation rests the development of the mineral wealth of a region, and its commercial importance in the mine products is hastened. Prospecting goes on in every community to a greater or less extent, but not always in an intelligent way. It is a widely known fact that the greater share of ordinary prospecting is not only carried on unprofitably, but much of it without a shaddow of hope of success. It is the province of a state to encourage intelligent search for mineral wealth and to nurture reasonable efforts in the development of the natural resources. This a state attempts to do by supporting a systematic geological survey; and perhaps no investment, either public or private, yields both directly and indirectly so great a return for the amount expended, as that placed by the citizens of the commonwealth to conduct a careful investigation into the mineral resources. The results supply just that information which enables intelligent prospecting to be carried on in every county and which prevents much of the useless expenditure of money, time, and labor in hopeless enterprises.

Wealthy corporations are able to spend large sums of money in developing mining districts. When local investigations of this kind are carried on the investigation partakes of the character of "expert" work. But the small land owner is prohibited on account of lack of means from making extended investigations. He must have something to guide him in what

he undertakes. From the reports of the areas surveyed with reasonable exactness and care, each citizen is able to make out just what not to expect, before beginning to prospect. When the researches are conducted in a systematic way over more or less extensive areas and under governmental auspices the work becomes "geological surveying" in contra distinction to private "expert" work. The primary objects of state surveys is to obtain a comprehensive insight into what the commonwealth has in natural resources, to take an inventory of the natural possessions of the district, and to set forth to the public accurate and reliable descriptions of the mineral contents. Accounts of this kind are eagerly sought after, not only by the citizens of the state but by many others outside, those residing in other states and foreign countries. The benefits arising are three-fold. To the land-owners it is of direct benefit in placing a substantial and increased valuation on the tracts surveyed; to the citizens at large is an encouragement to the further development of the region, and a stimulus to all industrial activities; to the investor, either at home or abroad, it is an authoritative guaranty, protecting him from the wiles of nomadic speculators, making him feel more secure in making investments and therefore more ready to advance a much higher rate than he otherwise would feel justified in doing.

In all economic geological inquiry the work divides itself naturally into two classes both of which, while apparently sometimes covering the same ground, are very different. They form rather two parallel lines of investigation which supplement each other so that nowhere is there a duplication of efforts. One of these lines considers a particular deposit for an entire province, and is commonly denominated subject work. The other treats of all deposits of a useful character which are found in a given district and is technically termed areal work. Reports on counties, "sheets," or other limited districts are results in areal work. The former is a consideration of the properties, uses and methods of development, of the manipulation of the different deposits and the kinds occurring in the various localities. The second notes the extent, adapt-

ability and accessibility of deposits as found in particular places.

The work of the earlier geological reconnoissances was a mixture of the areal and the subject, reports on the county being the most common unit as the basis of presentation. But the reports of a quarter of a century ago were very different from those of the present day, and in most places were largely preliminary, especially in this country. They differ from the modern areal reports in embracing also much general matter and thus to some degree they covered both fields, but neither of them fully. Furthermore, natural history was commonly included and this took up no small part of the means and efforts. The areal reports of to-day are confined almost entirely to the mineral resources. They are very much more extensive and much more practical than the earlier accounts. Detailed information of a local character is considered; the present and possible future developments of the mineral wealth are set forth. Its direct purpose is to satisfy constant and every increasing demands for reliable information in regard to given localities. The desire to know about the mineral products of each particular neighborhood is so general that full details are required concerning every substance which is, or is likely to be of value, to the land-owner, or occupant, in the district. Probably one-half of the people making inquiry seek information of a local character.

The disemination of useful information regarding particular districts is accomplished in three ways; first by descriptions and sections; second, by illustrations; and third, by maps. No less than three-fourths of the geological facts are recorded cartographically. In consequence, therefore, a modern geological map is a graphic summary of a vast amount of useful information. In addition to an accurate representation of the ordinary geographical features, as in the best atlases, a properly constructed geological map records much more. On it are indicated, within a few feet where the topography is represented properly, the elevations above the sea level of every point within the borders of the area; the drainage basins and the water powers; the distribution and limits of the different

geological formations, the various kinds of ores, building stones, clays, and all minerals of economic value contained in the several beds, as well as the best places for obtaining all of these substances. The map also forms a reliable soil index, which, with some additional explanation, serves also as a guide to the distribution of the forests and plants generally.

But all the districts considered cannot be treated alike in the mapping. Some places require far more work than others, either on account of the great importance of the mineral deposits or the natural difficulties caused by the ruggedness of the country. Other regions, as those which contain the principal iron ores, the most valuable lead and zinc deposits, or particular coal beds, require, in the beginning, accurate relief maps. Places where the immediate mineral wealth is not so great do not require so elaborate topographical maps. At the present time it is not advisable nor, even if it were desirable, would the resources of a state survey permit it without a very considerable enlargement of its powers. The work goes on as rapidly as is consistent with good and accurate results. In order of their importance must the various districts be mapped and in proportion to their natural wealth should the detail be recorded.

The preparation of a full set of maps of this kind is not the result of few day's effort, but of the labor of years. As a part of the systematic investigations carried on in regard to economic resources there should be prepared a series of maps which would embrace for every section of the district all of the information mentioned. Some of them need to be somewhat general in their character and ordinarily accompany the different special reports. Others should be more detailed in their make-up and cover given counties or such other areas as may be thought desirable. In the construction of maps showing the distribution and occurrence of mineral substances it is of prime importance that the surface relief should be depicted in a readily intelligible manner. One which represents most closely a perfect miniature of the surface of the region is far superior to any ordinary atlas. It is invaluable not alone to the trained geologist, but it is about the only practical way by

which the average citizen is able to comprehend, at a glance, the explanations. In proportion as the exactness with which the diminutive representation approaches the actual surface, in the same proportion does the usefulness of the work increase. The modern methods of making maps are so far advanced over those of a quarter of a century ago that it enables them to be made at a cost within the reach of all.

In brief, then, a properly constructed geological map of a district not only locates accurately the various mineral deposits, but also represents the prominent landscape features by which the locations may be more readily recognized. A relief map also served other purposes. Upon it may be based models of the more important districts which are to be taken as characteristic of much larger areas and which are to represent in a graphic manner the structure, arrangement and relations of deposits. Eventually a relief model of the entire district may be constructed on a suitable scale. Besides, for the purposes mentioned it would afford one of the most instructive objects for presenting to the pupils of schools the geographical features of their state. With the wide introduction of the new methods of teaching geography the value of such aids cannot be over-estimated.

The scope and aims of areal and subject work are quite different. The ground covered by the former has been outlined. The latter is primarily to satisfy a wide and ever increasing demand for information in regard to the existence, mode of occurrence, properties and commercial values of the various substances. Such deposits are not limited by ordinary political boundaries, but each kind of mineral, clay or other mineral product dug from the earth belongs to some particular geological formation; in other words, it is found at some horizon or level more plentiful than at others. Thus, one formation is abundantly supplied with coal; another with ores of zinc or lead; a third with materials for the manufacture of cements; and others with still different substances of economic value. Each is found in a particular geological zone and rarely or very sparingly elsewhere. Only within certain districts

would search for a given substance be successful; outside of these areas no amount of prospecting would ever disclose the material sought. When the information is obtained concerning any particular mineral substance the entire subject must be carefully considered. At the outset a clear understanding of the geological structure of the rocks containing it is of prime importance. The localities where it occurs require description. The arrangement, relations and extent of the deposits must be defined; the origin and properties discussed; the accessibility and value determined; the uses of the substances, the nature and status, both present and probable future of the industries connected, fully considered. A complete report on each special subject is therefore comprehensive in character and concise in statement. The work cannot be weighed with the details of only local interest, as this would extend the account far beyond the space that could be alloted to it. Information of an entirely local character must be recorded largely on maps or described in accounts of areas.

The neccessity of a dual arrangment of work in completing a thorough geological survey is obvious. On account of the magnitude of the work the investigations must necessarily extend over a period of years. The means usually provided by a province are far too inadequate to extend the detailed work over a whole state in a single year, and consequently in the beginning of the work some areas must be taken up first and finished, before others can be inquired into and mapped in detail. At the same time the work on various topics may go on over the whole region and the results of the investigations on the various deposits published and given to the public long before all the work of all of the counties or districts is done.

As the outcome of work done in important mining districts the accompanying volume comprises the areas covered by sheets one to four, and is the first of the series of reports on areal geology, issued by the Missouri Geological Survey.

GEOLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

SHEET REPORT No. 1.

A REPORT ON

THE HIGGINSVILLE SHEET

Lafayette County

ACCOMPANIED BY

A Geologic and Topographic Map and a Sheet of Sections.

FROM FIELD WORK PROSECUTED DURING THE YEARS 1890 AND 1891.

BY

ARTHUR WINSLOW,

STATE GEOLOGIST

PUBLISHED BY

THE GEOLOGICAL SURVEY.

JEFFERSON CITY,
April, 1892.

PREFACE.

This report, with the accompanying map and section sheet, is the first of a series of similar reports which will be issued by the Geological Survey. They will contain the results of detailed examination in the respective areas. The localities selected for such work are those which are of prominent economic importance, or which are of great geologic and scientific interest. The scope and functions of such area work have already been described in a previous publication,* and will not be further discussed here. Suffice it to say that such work deals with all contained in a certain area, in distinction to subject work, which deals with special subjects for the whole State.

The maps of these reports embody in themselves a great mass of important information, and much time and care have been given to their preparation. The map accompanying this report is termed the Higginsville sheet, is a quarter of a degree long on each side, and occupies an area of one-sixteenth of a square degree of latitude and longitude, or about 230 square miles. The scale of the map is very nearly one mile to an inch.† The reasons for selecting this unit of area are that it is a fixed and permanent one, not subject to change by subdivision or otherwise, as in a county; that it can be represented on a sheet of a moderate and convenient size for reference, and that all sheets can be made of the same size and ultimately united in an atlas if desired. This same sheet unit is adopted by the U. S. Geological Survey, and the most recent maps of foreign government surveys are published on sheets of about

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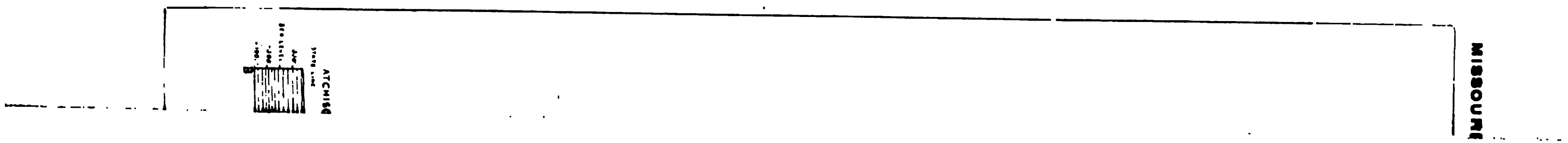
* Biennial report of the State Geologist, transmitted by the Bureau of Geology and Mines to the 36th General Assembly, pp. 34 to 38.

† The scale of the map is $\frac{1}{62500}$ of nature, whereas a map on a scale of one statute mile to the inch is $\frac{1}{63360}$ of nature. The object in adopting the former scale is to harmonize the work with the scheme of publication of similar maps of the U. S. Geological Survey, which are published on the former scale or on scales which are in simple ratio to this.

the same size or less. The tendency of modern map publication is toward the adoption of a small sheet. The universal applicability of the degree, or fraction of a degree, as a unit of publication commends the plan here adopted for general use.

The projection of the sheet was taken from the previously published Lexington sheet of the U. S. Geological Survey, which was based on the triangulations of the Coast and Geodetic Survey of the Missouri River Commission in this and adjacent counties: that is, the positions of the township and range lines with reference to the meridians and parallels were thus fixed. Within each cadestral township, so outlined, the section lines were located from the land office sheets, discrepancies within such townships being distributed. The railway lines were plotted from the maps of the respective roads, and these, together with the section and other land division lines, served as lines of horizontal control. The drainage has been plotted in part from the land office sheets; at least the points of intersection of streams and section lines have been generally obtained in this way. Such locations are, however, checked by frequent intersections with the meander lines of the topographic work. Vertical control for contouring was obtained primarily from the precise leveling of the Missouri River Commission along the river, and, secondarily, from the profiles of the various railways. In addition to these, lines of level have been run by the Geological Survey through each township, thereby furnishing frequent bench-marks, and, in addition, fixing with exactness the relative elevations of coal beds and topographic features of special importance. Between these lines altitudes have been determined by aneroid barometer measurements along the lines of meander surveys. Such meander work was performed with hand compass and paced distances following along roads or along section or other land lines, and in all cases checked by frequent intersection with such lines. In these surveys the topography was sketched at the same time directly into the note-book, and all observed geological occurrences were located in their proper topographical positions.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In all economic geological inquiry the work divides itself naturally into two classes both of which, while apparently sometimes covering the same ground, are very different. They form rather two parallel lines of investigation which supplement each other so that nowhere is there a duplication of efforts. One of these lines considers a particular deposit for an entire province, and is commonly denominated subject work. The other treats of all deposits of a useful character which are found in a given district and is technically termed areal work. Reports on counties, "sheets," or other limited districts are results in areal work. The former is a consideration of the properties, uses and methods of development, of the manipulation of the different deposits and the kinds occurring in the various localities. The second notes the extent, adapt-

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The scope and aims of areal and subject work are quite different. The ground covered by the former has been outlined. The latter is primarily to satisfy a wide and ever increasing demand for information in regard to the existence, mode of occurrence, properties and commercial values of the various substances. Such deposits are not limited by ordinary political boundaries, but each kind of mineral, clay or other mineral product dug from the earth belongs to some particular geological formation; in other words, it is found at some horizon or level more plentiful than at others. Thus, one formation is abundantly supplied with coal; another with ores of zinc or lead; a third with materials for the manufacture of cements; and others with still different substances of economic value. Each is found in a particular geological zone and rarely or very sparingly elsewhere. Only within certain districts

would search for a given substance be successful; outside of these areas no amount of prospecting would ever disclose the material sought. When the information is obtained concerning any particular mineral substance the entire subject must be carefully considered. At the outset a clear understanding of the geological structure of the rocks containing it is of prime importance. The localities where it occurs require description. The arrangement, relations and extent of the deposits must be defined; the origin and properties discussed; the accessibility and value determined; the uses of the substances, the nature and status, both present and probable future of the industries connected, fully considered. A complete report on each special subject is therefore comprehensive in character and concise in statement. The work cannot be weighed with the details of only local interest, as this would extend the account far beyond the space that could be alloted to it. Information of an entirely local character must be recorded largely on maps or described in accounts of areas.

The neccessity of a dual arrangment of work in completing a thorough geological survey is obvious. On account of the magnitude of the work the investigations must necessarily extend over a period of years. The means usually provided by a province are far too inadequate to extend the detailed work over a whole state in a single year, and consequently in the beginning of the work some areas must be taken up first and finished, before others can be inquired into and mapped in detail. At the same time the work on various topics may go on over the whole region and the results of the investigations on the various deposits published and given to the public long before all the work of all of the counties or districts is done.

As the outcome of work done in important mining districts the accompanying volume comprises the areas covered by sheets one to four, and is the first of the series of reports on areal geology, issued by the Missouri Geological Survey.

GEOLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

SHEET REPORT No. 1.

A REPORT ON

THE HIGGINSVILLE SHEET

Lafayette County

ACCOMPANIED BY

A Geologic and Topographic Map and a Sheet of Sections.

FROM FIELD WORK PROSECUTED DURING THE YEARS 1890 AND 1891.

BY

ARTHUR WINSLOW,

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PUBLISHED BY

THE GEOLOGICAL SURVEY.

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PREFACE.

This report, with the accompanying map and section sheet, is the first of a series of similar reports which will be issued by the Geological Survey. They will contain the results of detailed examination in the respective areas. The localities selected for such work are those which are of prominent economic importance, or which are of great geologic and scientific interest. The scope and functions of such area work have already been described in a previous publication,* and will not be further discussed here. Suffice it to say that such work deals with all contained in a certain area, in distinction to subject work, which deals with special subjects for the whole State.

The maps of these reports embody in themselves a great mass of important information, and much time and care have been given to their preparation. The map accompanying this report is termed the Higginsville sheet, is a quarter of a degree long on each side, and occupies an area of one-sixteenth of a square degree of latitude and longitude, or about 230 square miles. The scale of the map is very nearly one mile to an inch.† The reasons for selecting this unit of area are that it is a fixed and permanent one, not subject to change by subdivision or otherwise, as in a county; that it can be represented on a sheet of a moderate and convenient size for reference, and that all sheets can be made of the same size and ultimately united in an atlas if desired. This same sheet unit is adopted by the U. S. Geological Survey, and the most recent maps of foreign government surveys are published on sheets of about

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* Biennial report of the State Geologist, transmitted by the Bureau of Geology and Mines to the 36th General Assembly, pp. 34 to 38.

† The scale of the map is $\frac{1}{62500}$ of nature, whereas a map on a scale of one statute mile to the inch is $\frac{1}{63360}$ of nature. The object in adopting the former scale is to harmonize the work with the scheme of publication of similar maps of the U. S. Geological Survey, which are published on the former scale or on scales which are in simple ratio to this.

the same size or less. The tendency of modern map publication is toward the adoption of a small sheet. The universal applicability of the degree, or fraction of a degree, as a unit of publication commends the plan here adopted for general use.

The projection of the sheet was taken from the previously published Lexington sheet of the U. S. Geological Survey, which was based on the triangulations of the Coast and Geodetic Survey of the Missouri River Commission in this and adjacent counties: that is, the positions of the township and range lines with reference to the meridians and parallels were thus fixed. Within each cadestral township, so outlined, the section lines were located from the land office sheets, discrepancies within such townships being distributed. The railway lines were plotted from the maps of the respective roads, and these, together with the section and other land division lines, served as lines of horizontal control. The drainage has been plotted in part from the land office sheets; at least the points of intersection of streams and section lines have been generally obtained in this way. Such locations are, however, checked by frequent intersections with the meander lines of the topographic work. Vertical control for contouring was obtained primarily from the precise leveling of the Missouri River Commission along the river, and, secondarily, from the profiles of the various railways. In addition to these, lines of level have been run by the Geological Survey through each township, thereby furnishing frequent bench-marks, and, in addition, fixing with exactness the relative elevations of coal beds and topographic features of special importance. Between these lines altitudes have been determined by aneroid barometer measurements along the lines of meander surveys. Such meander work was performed with hand compass and paced distances following along roads or along section or other land lines, and in all cases checked by frequent intersection with such lines. In these surveys the topography was sketched at the same time directly into the note-book, and all observed geological occurrences were located in their proper topographical positions.

MISSOURI

These methods were accepted as adequate for the construction of a topographic map for the present purposes on the scale and with the contour interval used. More must not, therefore, be demanded of such maps than these considerations warrant, though they will prove of value in the future for many other industrial and scientific uses than those for which they were especially constructed. They portray with exactness the distribution of upland and lowland, and, with reasonable faithfulness, the relative elevations of the various hills. It is not maintained that the exact amount of grading necessary for the construction of a railway across the areas represented on such maps can be calculated from their study; yet, on the other hand, the general question of the practicability of construction along any line can be determined at a glance.

In addition to the topographic base, the distribution of the geological formations is clearly shown on the map by the different colors. The flat shades of gray used for the divisions of the Coal Measures have been adopted after experimentation with various color schemes. It was found that any scheme involving the use of a series of over-printed patterns could not be introduced on maps containing so much other detail as do these, without seriously obscuring the latter. In addition to such general geologic delineation, it will be observed that many outcrops are located on the map. These are generally outcrops of special importance for the correlation of sections. The horizon lines of important coal beds are also introduced. Such a line is shown where there is reason to believe that the particular bed is actually present. Elsewhere it is omitted, to indicate the fact that the existence of the bed is not recognized, even though there is no geologic break between the two areas, and, strictly speaking, the geologic horizon of the coal bed is still present. On the other hand, however, for manifest reasons, no allowance is made in the location of the horizon line for the covering of superficial material. Thus, where the thickness of the latter is great, and the hill slope slight, the actual limits of a coal bed are well within the horizon line shown on the map. This accounts, in cases, for the absence of coal in wells or drill

holes within the limits assigned a coal bed. The depth of such superficial material is so variable that it is impossible to predicate just how far within the plotted horizon line the coal terminates at all points. Such details must be settled by observation and prospecting at each locality. This influence of the superficial material must always be considered in interpreting such representation of horizon lines.

The report accompanying this map is made as exhaustive as the status of the work of the Survey will permit. It includes the results immediately relating to this area which are published in reports of earlier surveys, in addition to the large amount of data which were collected along with the recent mapping. The more prominent mineral products are described in greater or less fullness, in proportion to their importance. Some of these will be subjects of further investigation in the future, but it was deemed inexpedient to postpone the publication of the sheet report until this supplementary work was completed.

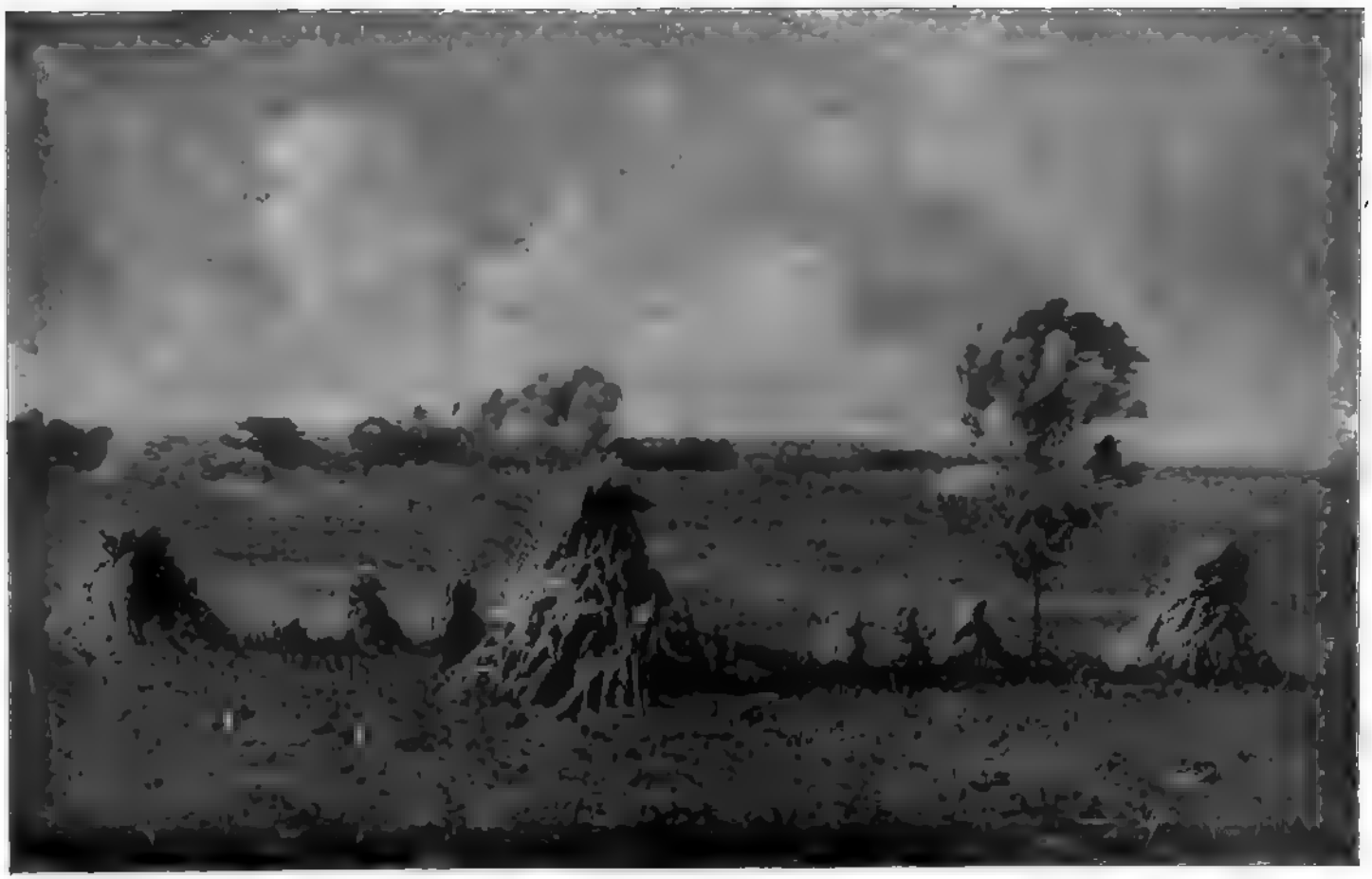
The coal analyses were all made by Mr. J. D. Robertson in the Survey laboratory. The samples are originally collected in air-tight fruit jars and are preserved in these. A portion for analysis was taken from such a jar and ground to a powder, and then exposed to the air for a period of about two days to rid it of excessive moisture. The moisture was determined by subsequently heating in an air-bath for one hour, at a temperature of 105° to 110° C. The volatile hydrocarbon was determined by successively heating a fresh portion of the coal in a closed crucible, for 3½ minutes over the Bunsen burner and then over the blast lamp; the fixed carbon, by ignition of the remaining carbon or coke in the open crucible. The total sulphur was determined by the Eschka method; the sulphur in the ash by fusion with potassium and sodium carbonates and a little potassium nitrate, solution and precipitation as barium sulphate.

As many of these coals contain visibly considerable amounts of selenite, or sulphate of lime, it was thought that this constituent might account for a large part of the total sulphur con-

tained in Missouri coals. To decide this the determinations of the sulphur in the ash were made. The difference between the total sulphur and the sulphur in the ash is the sulphur which goes off in the combustion of the coal, and may thus be considered the deleterious sulphur in most processes of combustion. The small amounts of sulphur which the analyses show to exist in the ashes make these determinations of less value industrially than was anticipated.

Upon the section sheet accompanying the map are drawings prepared from the records of various drill-holes, and in the text are descriptions of others. These records are mostly derived from work with the churn drill, by miners or well-drillers of the county. With some only imperfect notes were preserved, and with few could actual samples of the drillings be examined by the Survey. The results are presented as the best attainable, but are to be accepted with the reservations which attach themselves to all data so derived.

The geology of the area was specially studied by the writer, and all important coal openings were visited by him. The field work for the topographic map was done by Mr. Leo Gluck and Mr. C. F. Marbut under the writer's direction; in addition they located the various coal and other outcrops, and collected other notes which have been incorporated in the report. Prof. J. E. Todd made a special study of the Quaternary deposits and prepared the section on that formation, printed herewith. Mr. Gilbert Van Ingen, of the U. S. Geological Survey, made certain observations on the Warrensburg sandstone which are incorporated.



VIEW IN LAFAYETTE COUNTY.

REPORT ON HIGGINSVILLE SHEET.

BY ARTHUR WINSLOW, STATE GEOLOGIST.

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INTRODUCTION.

AREA AND LOCATION—RAILWAYS—TOWNS—INDUSTRIES.

The Higginsville sheet is in Lafayette county and is named from the town of Higginsville, located in the southwestern portion of the area.

AREA AND LOCATION.

The area represented by the sheet is a quadrilateral of 15′ extent in latitude and longitude, embracing an area of 231.67 square miles. It is included between the lines 39° 00′ and 39° 15′ of latitude, and the lines 93° 30′ and 93° 45′ of longitude west of Greenwich. Its position in the State may be termed western-central, inasmuch as it is only 50 miles east of the western boundary of the State, at Kansas City, and 100 and 180 miles from the northern and southern boundaries respectively. It lies principally south of the Missouri river, that stream traversing the area close to its northern boundary. It covers nearly the entire half of Lafayette county, the eastern border being less than a mile west of the Lafayette-Saline county line, and the southern border being about five miles north of the Lafayette-Johnson county line. North of the Missouri river some twenty miles of Ray county are also included. The location with reference to the county lines is shown on the following diagram:

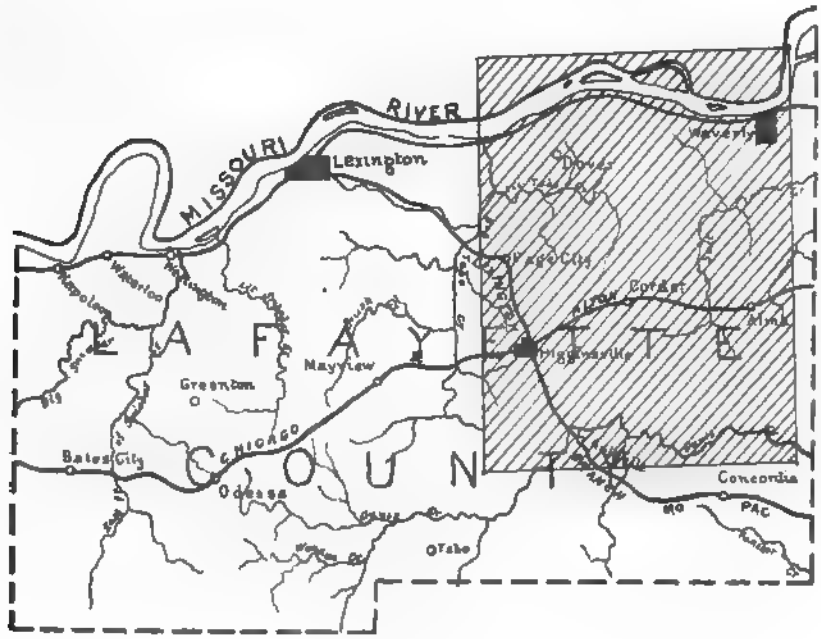

FIG 1. Outline map showing the position of the Higginsville sheet in Lafayette county

RAILWAYS.

Three railway lines traverse the sheet, namely: the Chicago & Alton railway, centrally from east to west, through Alma, Corder and Higginsville; the Lexington branch of the Missouri Pacific, across the southwestern corner, through Aullville, Higginsville and Page City; and the Jefferson City & Boonville branch of the Missouri Pacific, across the northern portion of the sheet, along the south bank of the Missouri river. The Chicago & Alton is part of the main line between Chicago and Kansas City; and a very large amount of freight passes over it annually. The other lines are branch roads of the main line, and, though large quantities of coal, grain and other produce are shipped over them, they are not so important lines of traffic as is the Chicago & Alton.

TOWNS.

The towns and villages within the area of the Higginsville sheet, in the order of their importance are:

1. Higginsville, population about..... 2342 *
2. Corder, " " ....1145 *
3. Waverly, " " .... 826 *
4. Dover, " " .... 200 (?)
5. Alma, " " ... . 179 *
6. Aullville, " " ..... 100 (?)

Higginsville is a trade center, which, like all other towns of this country, owes its existence primarily to the rich agricultural lands which surround it. Its prominence is largely due to the fact that it is at the junction of two railway lines. The coal mines in the immediate vicinity give employment to a large number of its citizens. Another prominent industry is the drain-tile and brick manufacture. The town contains a large flouring mill, a grain elevator, a carriage factory and warehouses for fruit storage.

Corder is largely supported by the country trade. One coal mine is operated here, which is also a large contributor to the business of the place. One flouring mill and one grain elevator are here.

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*From figures of the Eleventh United States Census.

Waverly was, in years past, when the river traffic was active, a large shipping point and a place of much business activity and prosperity. During late years it has, however, retrograded and is supported only by a meager trade derived from the adjacent country. During the past year, however, the discovery of coal at this point has started mining here which bids fair to cause a revival of prosperity.

Dover is, like Waverly, an old town, formerly supported by the river trade, but now sunk into a dormant condition. No special industries characterize the place, and it is supported merely by a small local trade.

Alma is a place only a few years old, and is, at present, merely a local trade and shipping point. It has a grain elevator, and drain-tiles and brick are also manufactured here.

Aullville is, similarly, only a small local trading and shipping point with a grain elevator and fruit storage warehouse.

INDUSTRIES.

The industries of the area are chiefly agriculture and mining. The value of the agricultural products is much in excess of those from mining, the area being in one of the most fertile sections of the State. These products consist chiefly of wheat and corn, and in addition large numbers of cattle and hogs are raised and shipped.† Coal is the only mineral substance which is mined to a large extent. Clays are manufactured at a number of points into drain-tile and brick, as already indicated. A few small quarries have also been opened and are worked intermittently for local uses, and in connection with railway construction; more will be said of these later.

†According to figures collected by Hon. Willard C. Hall, State Labor Commissioner, the values of the various products shipped from the different railway points in Lafayette county during the year 1890 were, in round numbers: Wheat, $500,000; corn, $80,000; cattle, $330,000; hogs, $240,000; coal, $400,000.

PHYSIOGRAPHY.

TOPOGRAPHY—HYDROGRAPHY—SOILS—FORESTRY

TOPOGRAPHY.

Topographically, the area represented by the Higginsville sheet is a plateau in which erosion has proceeded far. It is in what is called a "mature" stage of topographic development. A drainage system is well developed, and base-leveling is in progress along the Missouri river and along the larger of the tributary streams, such as Tabo, Davis and Salt creeks. It is

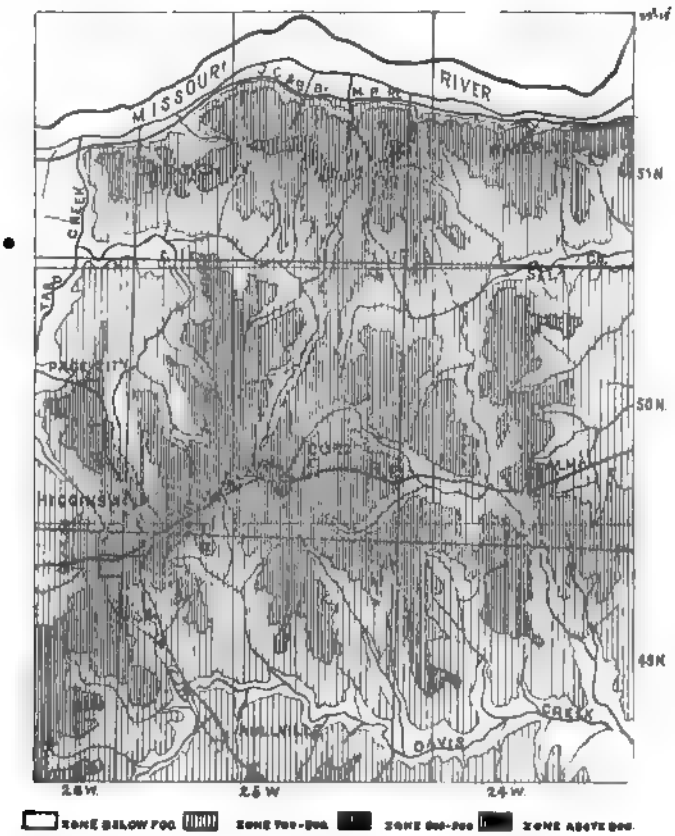

FIG. 2 Hypsometric diagram of the Higginsville sheet

composed of horizonal strata of varying degrees of hardness a plateau situated at a moderate elevation above sea-level, and durability, overspread by a thick mantle of drift which forms a soil of extreme fertility, and located in a region of which the climate is most conducive to the growth of vegetation.

As a result of the first of these conditions, the moderate altitude, the differences of elevation are not great. The altitude of the flood-plain of the Missouri river varies from about 660 ft. A. T. to 630 ft. A. T., and that of the highest summits is about 900 ft. A. T.; hence, the maximum difference is a little over 200 ft. The distribution of different zones of elevation is well displayed on the preceding diagram.

The altitudes of the flood plains of the principal tributaries of the Missouri are in the vicinity of 700 ft. A. T., which is very little above the plain of that river. Hence, it will be readily understood that these streams can corrade or lower their channels little, if any, below their respective levels. For convenience of use and reference the following table of altitudes is here introduced:

TABLE OF ALTITUDES TO THE NEAREST FOOT OF RAILWAY STATIONS IN THE AREA OF THE HIGGINSVILLE SHEET.*

ALMA, C. & A. R'y		809	ft. A. T.
AULLVILLE, MO. P. R'y.		722	" "
CORDER, C. & A. R'y		872	" "
DOVER, MO. P. R'y		679	" "
EDWARDS STATION, MO. P. R'y		675	" "
HIGGINSVILLE,	C. & A. R'y.	834	" "
	MO. P. R'y	819	" "
PAGE CITY, MO. P. R'y		780	" "

As a result of the condition of horizontality of the strata we have the irregularly undulating surface and the broad, flat-topped hills. Long, narrow-crested ridges are entirely absent.

The process of degradation by reason of the conditions of variable hardness and variable durability of the strata is well displayed along the Missouri river, where active erosion has developed a line of steep bluffs over 100 feet high, in which the strata of limestone or shale are frequently well exposed.

* On the topographic map accompanying this report many details of elevation are incorporated. Further reference to such is hence omitted here.

Here the disintegration of the softer rocks, and the consequent undermining of over-lying hard strata, is clearly to be recognized as the controlling action of erosion. Away from this stream, however, bluffs and steep declivities are rare, the country is more what is called rolling, and the details of the effects of stratigraphy are hidden by the mantle-like covering of loess. The climatic conditions and the abundant vegetation are most effective here in retarding the work of erosion, and preventing the formation of gullies and ravines. Were the country arid and barren, with little soil, the topography would be of a rugged type, consisting of flat-topped hills bounded by abrupt ravines or canyons; the characteristic profile would be a serrated rather than an undulating one.

HYDROGRAPHY.

The entire area of the sheet is part of the drainage basin of the Missouri river. This stream traverses the northern portion. It is there seen to be bordered by broad, alluvial plains on the northern side, whereas on the southern side it flows close to the bluffs. It was at one time a great avenue of travel and a source of support to the various small towns and villages scattered along its banks. The extension of railways has, however, now reduced river traffic to a minimum, and has caused the decay of many of these small centers of trade. The depth of water in the channel is very fluctuating, and this has also, in part, caused the partial abandonment of steamboating. During the spring and early summer months the water is generally high; while during the late autumn and winter months it is generally so low as to prevent the passage of the larger freight boats, to which the river is open at other seasons of the year. The extent and distribution of sand-bars are well displayed on the sheet, and the obstruction they offer to free navigation can readily be imagined.

The principal tributaries of the Missouri traversing this area are: Tabo creek, Davis creek and Salt creek.

Tabo creek is represented in the northwestern corner just before it empties into the river. It is a stream only about 15

miles long, which rises in Lafayette county. Within the area mapped it is bordered by alluvial plains, and has reached its base level.

Davis creek traverses the southern portion of the sheet. It also rises in Lafayette county, about fifteen miles above Aullville, and it empties into Black fork of the Lamine river at Sweet Springs, about fifteen milles below Aullville. Broad alluvial plains, of great fertility, flank the stream along its whole length within the area of the sheet. It is to be noticed that the level of this plain, near the eastern border, is not more than 15 ft. above the level of the river plain immediately north of this point. Base levelling is hence in progress here, and corrasion of the channel is slight or nil.

Salt Creek rises within the limits of the sheet and flows through the northeastern corner. It constitutes the upper portion of the Salt fork of Lamine river, which flows through Saline county, and empties into Black fork above the confluence of the latter with the Lamine river. The channel of this stream, within the sheet, is some 20 ft. higher than that of Davis creek to the south, despite the greater proximity of the former to the river. Its flood plains are, hence, narrower and corrasion probably more active.

In general, the drainage system of the area mapped is well developed and the main drainage channels permanently established. The general outlines of the drainage areas of the respective streams are shown in the small cut on page 13, representing the hypsometry of the sheet.

The waters of the streams are derived from surface flows, or from percolation through the superficial clays and loams. No large springs exist here, such as are found in the countries of massive limestone beds; in fact, surface springs of all kinds are scarce.

SOILS.

The soils may be divided into two classes, *residuary* and *foreign*.

Residuary soils are such as have resulted from the decomposition or decay *in situ* of the country rock, and are, hence, in

any locality, dependent in character upon the nature of the underlying rock. All rocks are decomposed, to a greater or less extent, through the action of surface waters; the soluble constituents are carried away, while the insoluble ones remain and constitute the soils. Residuary soils are represented only over small portions of the area of the Higginsville sheet. They are found where the rock is near the surface, along hill slopes where the wash has been severe, along small streams of which the declivity is great. Over the area underlain by the Warrensburg sandstone such soils are of a sandy nature; over the surrounding areas, underlain by shales and limestones, they are generally argillaceous and may be calcareous.

Foreign soils of two kinds are represented here: *i. e.*, soils derived from alluvium and soils derived from drift.

The alluvial soils are found over the flood plains of the Missouri river and of the larger tributaries. They are composed of the silts carried down the streams from points above and deposited over the plains in times of flood. They hence are composed exclusively of material occurring over the drainage areas of the respective streams, though a large portion of these may be derived from the drift, inasmuch as the alluvium is of later origin. Such alluvial silts are generally rich in organic matter derived from the remains of vegetation transported by the waters. They are light, siliceous, rich loams, and they make the alluvial plains of the rivers, where well drained, the most productive farming lands in the State. The total area of such lands within the Higginsville sheet is about 42 square miles, and of this, about 25 square miles is north of the river. The soils of the drift occupy by far the greater area. The exact limits of the formation are described on subsequent pages. Within these limits it is everywhere present, excepting where the slopes are too steep for any soil to rest, or where it is covered by alluvium. The material is what is known as loess, which is normally a silt of light gray color, composed of extremely fine particles of quartz and associated materials which are found in other glacial deposits. They are derived from a remote source

to the north and were brought to their present locations through glacial action. The loess is the finely ground portion of a great mass of material which was transported by the glacier; it represents the portion which was floated away by water from the edge of the glacier and deposited over the bottom of a great marginal lake or stream. It is porous, homogeneous and pulverulent and constitutes the basis of a most admirable soil. It is absorbent and yet easily drained; it is easily tilled and is free from rocks. To this glacial covering of loess the country owes its distinction as a rich agricultural region.

The color of the soil here is generally rich and dark, sometimes almost back. This is not the original color of the materials from which the soil is derived, but is an acquired one, and does not generally extend below the depth of two or three feet. The origin of this color here has not been made a subject of exact investigation, but what seems a probable explanation is, that it is due largely to the prairie and forest fires which were once so common here. These would naturally cover ground with charred remains of grass and wood, which would impart the dark color to subsequently falling rain-water, and this, in turn, would transmit the color by percolation to lower depths. A succession of such fires for many years can readily be conceived as an adequate cause for the coloration of the soil to depths of several feet.

FORESTRY.

The greater part of this sheet has been and still continues to be what is known as prairie country, and is destitute of forest trees. Outside of certain limited areas of thin and poor soil over which a scrubby growth of oak has sprung up, timber is confined to the neighborhood of the streams.

The most common trees found here, according to determinations made by Mr. C. F. Marbut, an assistant of the Survey, are the black oak (*Quercus tinctora*, and probably *Q. coccinea* and *Q. rubra*), the white oak (*Q. alba*), the water oak (*Q. aquatica*), the laurel oak (*Q. imbricaria*), the slippery elm (*Ulmus fulva*), the American elm (*U. Americana*), the cotton-

wood (*Populus monilifera*), the white maple (*Acer dasycarpum*), and the linden (*Tilia Americana*). Of rarer occurrence are the swamp white oak (*Quercus bicolor*), the black-jack (*Q. nigra*), the black walnut (*Juglans nigra*), the buckeye (*Æsculus glabra*), the wild cherry (*Prunus Pennsylvanica*), the red-bud (*Cercis Canadensis*), the pawpaw (*Asimina triloba*), the white ash (*Fraxinus Americanus*), the sycamore or buttonwood (*Platanus occidentalis*, very rare), and the hickory (*Carya*—, very few.)

The general distribution of forest trees within the area is shown on the accompanying outline map.

Concerning the distribution of the trees Mr. Marbut reports as follows: "The timber of the area of the Higginsville sheet is almost wholly confined to the Missouri river bluffs and to a narrow belt along the bottoms of Davis and Tabo creeks and their tributaries. A little timber occurs along Salt creek bottom toward its upper part; but most of the bottom, after its course changes to an eastward one, is open excepting for a few willows on the banks.

"The timber belt along the river averages about two miles in width. The principal growth is black-oak, white-oak, linden, elm, cottonwood, with scattered post-oaks, hickories, black walnuts, wild cherries, mulberries and blackberries, and a few others of no value for timber. The tops of the ridges are occupied by the black-oaks and white-oaks, though the white-oaks are more frequent on the hill-sides. Post-oaks are very rare, occurring only on flat uplands. The linden trees are found along the rich hill-sides and in the bottoms. They grow to a very large size and are used for lumber. Elms grow in the bottoms. Black walnut timber is not very plentiful. It is sometimes found around old farm-houses or old towns.

"The timber belt along Tabo creek is an extension of the Missouri river belt; but as one proceeds from the river the tree growth changes. The trees most met with along this belt are the elms, the maple and the laurel (probably willow) oak. This oak is the most common on the flat bottoms away from the vicinity of the streams, and on the wet lands of the adjoining uplands and tributaries.

"The timber belt along Davis creek is composed principally of elms and oaks, with cottonwood, black walnut, hickory, mulberry, ash and cherry, the latter being somewhat rare.

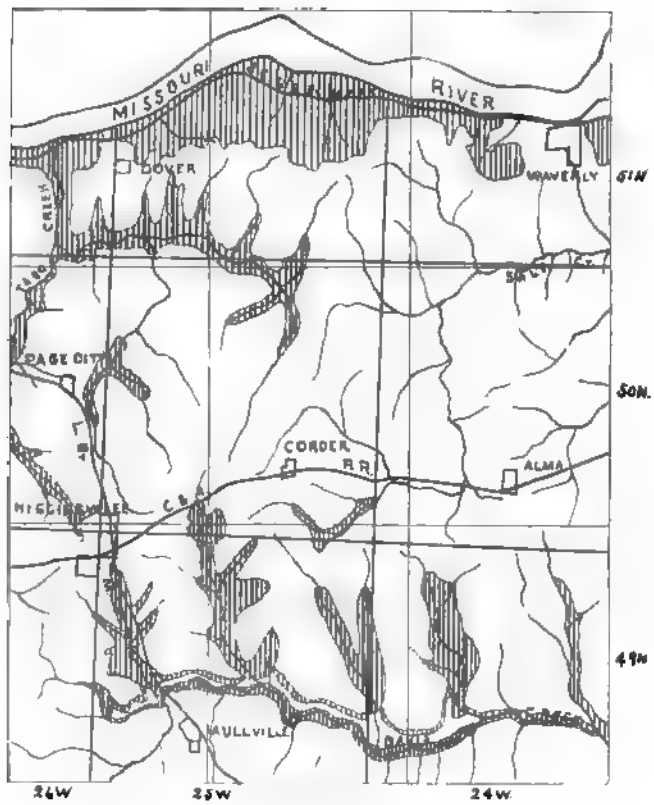

FIG. 3. Outline map showing distribution of forest trees within the Higgins ville sheet

"Southwest of Corder, in section 33, township 50 N., 25 W., and in sections 3, 4 and 5 of township 49 N., 25 W., is a small timber area consisting principally of black-oak, which especially characterizes the tops and sides of the hills. In the creek the black-oaks are replaced by elms and willow-oaks. Continuing down the creek toward Aullville, a scrubby growth of post oaks replaces the above. This growth is found in the

western part of sections 3 and 13, and in the eastern part of section 4, township 49 N., 25 W.

"Along the larger streams flowing into Davis creek, in township 49 N., 24 W., is a growth of black-oaks of small size, with elms. These occur generally over the bottoms, but along the tops of the hills on the north side of the creek is a growth of scrubby post-oak, which has sprung up in the sandy, uncultivated soil.

"The growth along the Missouri Pacific railway between Aullville and Higginsville, is principally elm and oak (black) and willow.

"In township 50 N., 24 W. are a few groves of cottonwood in the flat bottoms of the small branches, and cottonwood trees are frequently met with in the moist rich soil of the prairie branches. On the sand-bars in the Missouri river are a few sycamores. No linn trees were noted excepting along the Missouri river bluffs. Such may, however, occur scattered along the bottom of the large creeks. White-oaks are rare, occurring, so far as remembered, only along the Missouri river bluffs."

GEOLOGY.

STRATIGRAPHIC GEOLOGY—STRUCTURAL GEOLOGY—ECONOMIC GEOLOGY.

STRATIGRAPHIC GEOLOGY.

The formations represented within the area of the Higginsville sheet are clastic or stratified rocks and superficial deposits. The clastic rocks belong to the Carboniferous period, and to the Coal Measure division of that period, of which the lower and middle subdivisions and the Warrensburg sandstone occur at the surface. The superficial deposits belong to the Pleistocene or Quaternary period and include glacial drift, Loess and Alluvium. Diagramatically the classification of the rocks found here may be represented as follows:

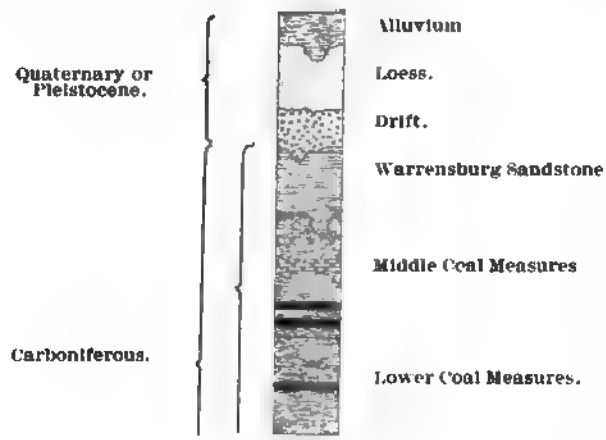

FIG. 4. Diagram showing the Geological formations exposed in the Higginsville sheet

THE LOWER COAL MEASURES.

The Lower Coal Measure rocks are exposed only over a small part of the area described, they being confined to the low-lying portions along the streams, mostly below the 750 ft. contour line. The total superficial area within which these rocks reach the surface is about 53 sq. miles, distributed along the Missouri river, along Davis creek, along Salt creek and along a fork of Tabo creek, as is shown on the map.

The line of delimitation here, between this formation and the overlying Middle Coal Measures, is placed at about 70 ft. below the Lexington coal bed, or about 20 ft. below the Mulky coal bed, both of which are included in the latter formation.*

The maximum thickness of the formation exposed at the surface here is not much more than 60 ft., and the maximum thickness penetrated at any one point is about 225 ft. This is, however, not the total thickness of the formation here, for the Lower Carboniferous rocks were not reached.

The rocks composing the various sections consist of shales, sandstones, clays, limestones and coals. The shales predominate and are frequently arenaceous; sandstones are probably more abundant and limestones less frequent than in the overlying Middle Coal Measures. In the southeastern portion of the sheet a sandstone bed, 10 or more feet in thickness, is taken as the uppermost bed of the Lower Coal Measures. This is, however, not persistent, and the transitions which have been observed of sandstone into shale lead one to the belief that none of the sandstone beds of this formation can be rigidly used for purposes of correlation.†

In illustration of the character and succession of the strata of this formation, the following series of sections is given:

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* In adopting this position for the line of division in the Higginsville sheet, we have followed Swallow's and Broadhead's guidance. (See Report Mo. Geological Survey, 1855, p. 85, and Report 1872, Part II, p. 83 and tables opposite p. 134 and p. 420.) The definition of this line has never been exactly expressed, and the so-called Lower Coal Measure area in this State is, to a certain extent, an unknown quantity. The reasons for this are probably certain errors in correlating exposures which Swallow was led into, which will hereinafter be referred to. Whether the stratigraphic conditions will permit of our carrying the horizon line here adopted across the whole State, can be proved only by the extension of detailed work. If this be found possible, the question will still remain as to whether either the faunal or lithologic characteristics of this assumed subdivision of the Coal Measures call for its formal differentiation from the overlying portions of the formation. For the present it is accepted, provisionally and largely from considerations of convenience in describing the great body of Coal Measure strata.

† Both Swallow (Op. Cit., p. 86) and Broadhead (Op. Cit., p. 5) described a bed of sandstone, some 75 feet thick, as constituting the uppermost bed of the Lower Coal Measures. The sandstones at Warrensburg, at Higginsville and on Tabo creek they recognize as belonging to this bed. The recent work of the Survey has demonstrated that the sandstones occurring at these localities belong much higher up in the section, as will be explained later, and that their great thicknesses are due to the peculiar conditions of their deposition. The sandstone above referred to by the writer as near the top of the Lower Coal Measures is not to be confounded with these massive deposits.

Sections along the Missouri river.—The best exposures of these rocks are along the Missouri river bluffs, as displayed in the cross sections A-B-C and D-E-F. About a mile east of the sheet limits, near the middle of section 13, township 51 N., 24 W., Edwin Harrison notes the occurrence of yellow, micaceous, sandy shale about 40 feet above the level of the railway,* which is probably the superior bed of the Lower Coal Measures.

The rocks above railway and river level at Waverly are hidden from view by a mantle of Loess over 100 feet thick. The line between the Lower and Middle Coal Measures is placed here at about 50 feet above the railway. About a quarter of a mile above the station is the shaft of the Waverly Coal and Mining Company. The top of the shaft is about 10 feet above the railway and it is 102 feet deep. It is consequently entirely in the Lower Coal Measures. A complete record of this shaft could not be obtained, but the following notes were furnished by the pit-boss:

SECTION 1.

SHAFT OF THE WAVERLY COAL AND MINING COMPANY,

A quarter of a mile East of Waverly.

Top of shaft about 10 feet above railway level.

		Ft.	In.
Interval to top of Lower Coal Measures about 30 feet			
1.	Interval	30	
2.	Coal and Shale	1	
3.	Interval	37	
4.	Coal		7
5.	Interval	15	
6.	Coal		5
7.	Interval	6	
8.	Coal		5
9.	Interval	5	
10.	Coal		8
11.	Shale, *gray, sandy*	6	
12.	Shale, *black, tough*	1	6
13.	Coal (*Waverly coal bed, operated*)	3	
14.	Shale, *gray, sandy*	4	10
15.	Shale, *gray*	18	
16.	Shale, *blue-black*	3	
17.	Shale, *black, hard*	4	
	Total thickness	136	5

*This and succeeding references to observations of Mr. Edwin Harrison are taken from carefully prepared manuscript notes which are now on file in the Survey office. These notes were written out by him in the year 1859, when he assisted Dr. J. G. Norwood in the examination of Lafayette county. Dr. B. F. Shumard was associated with Mr. Harrison in this work.

The frequency of coal beds here is especially noteworthy, as are, further, the absence of limestone beds and the prevalence of shale near the coal.

About a quarter of a mile west of this, near the depot, a trial shaft was put down to a depth of nearly a hundred feet. Of this shaft the following section was obtained from the superintendent:

SECTION II. (No. 2 of Section Sheet).

TRIAL SHAFT OF THE MIDDLETON COAL COMPANY,

On river bank at railway station.

Top of shaft about 10 feet below railway level.

Interval to top of Lower Coal Measures about 50 feet.		Feet.	Inches.
1.	Soil and loam	14	
2.	Sand	4	
3.	Shale, *greenish, with concretions*	3	6
4.	Shale, *black, hard*		2 to 3
5.	COAL		1
6.	Shale, *black, soft*		2 to 3
7.	Shale, *gray*	8	
8.	Limestone, *dark gray*	2	
9.	Shale, *gray*	8	
10.	COAL		1
11.	Clay		2
12.	Shale	17	3
13.	Limestone	4	6
14.	Shale, *dark brown, black near bottom with lamina of coal*	10	
15.	COAL (*Waverly bed, operated*)	3	
16.	Clay		
	Total thickness	75	0

About half a mile west of the depot, a thin seam of coal, about 9 inches thick, crops out in the railway cut, about 2 feet above the track. This must be a superior bed to any of those cited in the preceding sections.

Nearly half a mile beyond the last, at the mouth of Gladdish branch, which empties into the river just west of Waverly, the following section was measured:

SECTION III.

OUTCROP AT MOUTH OF GLADDISH BRANCH

Top of section is about 20 feet above level of railway.

Interval to top of Lower Coal Measures about 20 feet.		Feet.	Inches.
1.	Shale, *drab*	20	
2.	Shale, *black*		4
3.	COAL (*R'y level*)		7
4.	Shale, *blue*	18	
5.	Shales, *blue and black*	2	6
6.	Shale, *black, fissile*	1	6
	Total thickness	42	11

The coal of this section we correlate with that last mentioned. At this point another shaft has been sunk to the Waverly coal bed. The top of the shaft is about on a level with the railway, and it is 105 feet deep. (See detail of coal bed on section sheet.)

About a mile farther west, at the mouth of the McAffee branch, and nearly half a mile east of the line between sections 16 and 17, a bed of coal, about 9 inches thick, overlain by shales, is again encountered, nearly 10 feet below the railway level. This we also correlate with the coal bed of Section III. Some 600 feet beyond this to the west, the following section was measured:

SECTION IV.

OUTCROP NEAR MOUTH OF THE M'AFFEE BRANCH.

Top of section is about 30 feet above the railway.

Bottom of section is about 10 feet above coal last described.

Interval to top of Lower Coal Measures about 10 feet.	Feet.	Inches.
1. Sandstone	2	
2. Shale, *blue and gray*	18	
3. Sandstone, *irregular*	1	6
4. Shale, *blue and arenaceous*	6	
Total thickness	27	6

Beyond this, along the railway, for a distance of a mile and a half, to the line between sections 17 and 18, shales are exposed at frequent intervals in the railway cuts, sometimes to a thickness of 25 feet. At a few points, coal smut is noticeable, a few feet above the level of the railway, and this is assignable to a bed overlying the coal of Section III.

At the point where the line between sections 17 and 18 reaches the river, the following section was measured in the bluffs:

SECTION V. (No. 3 of Section Sheet.)

SECTION OF MISSOURI RIVER BLUFF, IN N. E. CORNER OF SECTION 18.

Top of section is about 50 feet above the railway.

Middle Coal Measures.	Feet.	Inches.
1. Shale, *gray*	3	
2. Limestone, *compact*	2	
3. Shale, *dark*	2	6
4. Shale, *black, fissile*	1	6
5. COAL *(Mulky bed)*	.....	1½
6. Fire-clay and concealed	10	
7. Shale, *gray, argillaceous*	20	

Lower Coal Measures.	Feet.	Inches.
8. Sandstone, *micaceous* (quarried for bridge piers)	4 to 5	
9. Shale, *drab*	10	
10. COAL, *bituminous* (at railway level)	.....	9
11. Concealed	13	
12. Shale, *black*, *fissile*	1	
13. COAL, *shaly* ("cannel")	.....	10
14. Concealed	4	
15. Sandstone, *bluish* (at water level)	2	
Total thickness	74	8^1_3

The coal bed numbered 5 we correlate with the Mulky bed, developed on Mulky creek, between Aullville and Concordia, near the south line of the sheet. The sandstone numbered 8 we class as the top member of the Lower Coal Measures, which is, hence, about 15 feet above the railway track. The coal numbered 10 is exposed farther east by the coal smut in the shales above referred to, while the coal numbered 13 we consider the equivalent of the coal numbered 3 in Section III.

Less than half a mile west of the last section a churn drill-hole was recently put down by Mr. H. S. Van Anglen, to a depth of about 200.

A few hundred feet west of the ravine in which this drill-hole is situated, at the mouth of a small branch, the coal bed numbered 10, of Section V, is again exposed below the railway level; it measures only a few inches in thickness, however; it is immediately underlain by a stratum of limestone two or three feet thick, and is overlain by gray shale.

In the next ravine to the west, perhaps 500 feet distant, several openings have been made in thin coal beds which occur there not far above the river level. These we correlate with those numbered 10 and 13 in Section V. Farther up this same gully, less than half a mile to the south, is a massive body of sandstone, exposed at the Davis quarry, underlain by shale. Here the following section was measured:

SECTION VI.

OUTCROP AT DAVIS QUARRY.

Top of section is about 60 feet above the railway.

	Feet.	Inches.
1. Limestone, *blue*	1	3
2. Sandstone, *shaly*	1	3
3. Sandstone, *yellow*, *micaceous*	12	
4. Shale, *dark drab*	20	
Total thickness	34	6

From the data of the sections previously described, the top of the Lower Coal Measures is less than 20 feet above the railway here, or more than 40 feet below the top of this section. According to this, the whole of Section VI should be included in the Middle Coal Measures near its base. Such strata are not recognized elsewhere as basal members of that division, and further, they are not represented in the closely adjoining Section V.

The continuity of the lower beds of Section V beneath Section VI precludes the idea of a fault here, and we are, hence, forced to the conclusion, either that a rapid change has taken place here in the lower members of the Middle Coal Measures, or that the members of the above section belong to the class of channel deposits later to be described.

Nearly a quarter of a mile farther west is a long railway cut, in which the following section was measured:

SECTION VII. (No. 4 of Section Sheet.)

OUTCROP IN RAILWAY CUT WEST OF DAVIS' QUARRY.

Top of section is about 26 feet above the railway.

Interval to top of Lower Coal Measures about 15 feet.	Feet.	Inches.
1. Shale, *gray*	3	
2. COAL, *bituminous*		6
3. Clay	1	
4. Limetone, *compact*	2	6
5. Concealed	15	
6. Shale, *black, fissile*	1	
7. COAL, *bituminous*		10
8. Clay *(railway level)*	3	
Total thickness	26	10

The coal numbered 7 we correlate with No. 10 of Section V. Nearly half a mile farther west, beyond where the range line between townships 24 W. and 25 W. comes down to the river, the following section was measured, at what is known as the locality of the old Crawford coal mine:

SECTION VIII. (No. 5 of Section Sheet.)

OUTCROP IN RIVER BLUFF AT CRAWFORD MINE.

Top of section is about 20 feet above the railway.

	Feet.	Inches.
1. Shale, *sandy*	10	
2. Sandstone, *micaceous, yellow (railway level)*	10	
3. Concealed *(sandstone blocks)*	15	
4. Shale, *dark and drab*	2	
5 Limestone (?), *dark*		5
6. Shale, *black, fissile*	1	3

		Feet.	Inches.
7.	COAL (*"cannel") and slate*	1	1
8.	COAL, *bituminous (water level)*	1	3
	Total thickness	46	0

The coal numbered 7 and 8 we correlate with No. 13 of Section V. The sandstone numbered 2 is probably the equivalent of No. 8 of Section V, much augmented in thickness. The absence of this sandstone in Section VII may be explained, in part, that it is there more attenuated, and, in part, that it is included in the concealed interval numbered 5. It is possible, however, that this sandstone is part of a channel deposit such as was suggested in the case of the sandstone of Section VI.* The coal here was dug from the river bed over 40 years ago, and hence the locality is known as the old Crawford mine.

The sandstone crops out continuously beyond this for a distance of about a quarter of a mile. After this no further outcrops of Lower Coal Measure rocks are observed until Edwards station is reached. Here a shaft was sunk by the Riverside Coal Company, about a year ago, to a depth of 93 feet in Lower Coal Measure rocks. A complete, reliable record could not be obtained of this, and the following information is compiled from memoranda of the drillers and shaft men:

SECTION IX. (No. 6 of Section Sheet.)

RECORD OF SHAFT AT EDWARDS STATION.

Top of shaft is about 20 feet above the railway.

Interval to top of Lower Coal Measures is about 10 feet.		Feet.	Inches.
1.	Superficial material	15	
2.	Shale	15	
3.	COAL		6
4.	Shale, *sandy and micaceous*	40	
5.	COAL, *slaty*		6
6.	Clay	3	
7.	Limestone (?)	3	
8.	Shale and clay	3	
9.	Limestone (?) *pyritiferous, clayey and fossiliferous*	1	8
10.	Shale, *black*	2	
11.	Shale, *hard, calcareous, black*		10
12.	Shale, *black, fissile*	2	
13.	COAL, *bituminous (operated)*	1	3
14.	Clay	4	6
	Total thickness	92	9

*Edwin Harrison, in his notes in the Survey office, refers to this sandstone as of Lower Coal Measure age and correlates it with the sandstone found at Berlin, near the mouth of Tabo creek, later to be described. Some black shale which he found at the base of this sandstone he attributes to a "slide" from shale overlying the latter.

The top of this shaft we place near the top of the Lower Coal Measures here, but we cannot attempt to correlate either of the coal seams with those of preceding sections, and in fact, doubt whether an actual connection exists. We do not recognize the bed at the bottom of the shaft as the Waverly bed, but are of the opinion that the latter belongc to a lower horizon.

About a quarter of a mile west of Edwards station, the following section was exposed in the railway cut:

SECTION X.

OUTCROP WEST OF EDWARDS STATION.

Top of section is about 18 feet above railway level.

Interval to top of Lower Coal Measures about 10 feet.	Feet.	Inches.
1. Limestone, *dark*	1	8
2. Shale	1	4
3. Concealed	1	
4 Shale, *black*		6
5. Clay, *blue*	5	
6. Concealed	2	6
7. Coal smut		2
8. Shale and concealed	5	
Total thickness	16	9

Near this same point, Mr. C. J. Norwood measured the following section :†

SECTION XI. (Section 29 of Report 1872.)

NORWOOD SECTION WEST OF EDWARDS STATION.

	Feet.	Inches.
1. Long slope. *(the Lexington coal should occur here 73 feet above the river bottom)*	55	
2. Limestone, *rough, gray, yellowish drab in parts*		15
3. Slope	25	
4. Shales, *hard*	5	
5. Limestone, *ashy blue, pyritiferous, shelly on top, Fusulina cylindrica, etc*		16
6. Shale, *bituminous*		18
7. Slope, *place for 7-in. bed of Lexington section*	5	
8. Limestone, *blue, three layers*		6
9. Clay, *blue*	5	
10. Limestone, *light yellowish drab, one bed contains Ch. mesoloba*	2	
11. Shale, *calcareous (passing into a limestone), containing concretions*	1	
12. Slope to bottom	22	
Total thickness	124	7

The top of the Lower Coal Measures should be not far above the lowest member of this section. East of this, to Tabo creek and to the limits of the sheet, only a few scattered

† Report Mo. Geol. Survey, 1872, Part II, p 49.

exposures of limestone and shale were observed at a low enough level to be included in the Lower Coal Measures. The Lexington coal bed comes in in the bluffs east of Edwards station at an altitude of about 800 feet A. T. or about 100 feet above the railway, and declines thence gently westward, the upper limit of the underlying Lower Coal Measures becoming depressed correspondingly until it sinks beneath the level of the river plain.

Sections along Salt creek and adjacent to Tabo creek.—Along Salt creek and in the small area of Lower Coal Measure rocks on the fork of the Tabo creek, east of Davis creek, no exposures of that formation occur, inasmuch as the upper line is in both localities very little above the level of the alluvial plain of the respective streams.

South of Davis creek, in the southeastern corner of section 4, township 50 N., 20 W., is a churn-drilled well on the Catron place, over 300 feet deep. No detailed record could be obtained of this drilling, but the following notes were given by the driller:

SECTION XII. (No. 1 of Section Sheet.)

RECORD OF CATRON WELL *(drilled)*.

Altitude of top of well about 790 feet A. T.

		Feet.	Inches.
1.	Superficial material	40	
2.	Shale	20	
3.	Limestone	9	
4.	Shale	1	6
5.	COAL	1	6
6	Shale, *with strata of limestone*	20	TOP OF LOWER COAL MEASURES
		160	
7.	COAL *(probably the Waverly bed)*	3	
8.	Interval	45	
9.	Sandstone	12	
	Total thickness	312	0

Sections along Davis creek.—North of Davis creek, in the eastern portion of the sheet, the Lower Coal Measure rocks are exposed, but no continuous sections can be measured at any one point. The records of a few wells obtained here give the most comprehensive results. The sandstone which constitutes the superior layer of the formation is exposed at a num-

ber of localities. The points of its most conspicuous occurrence are in the road in the N. E. ¼ of section 10, township 49 N., 24 W., where it is about 20 feet below the Mulky coal bed at the Corder shaft, a mile north; again on the branch in the N. W. ¼ of section 16 of the same township it is exposed, and on the hillside, in the S. W. ¼ of section 7, where several small quarries have been opened for local uses. In the N. E. ¼ of section 23 of township 49 N., 25 W., it has also been quarried to a small extent. The sandstone at these localities is uniformly of a buff color, is ferruginous and micaceous, and of a soft texture; it occurs generally in layers ranging from 6 to 18 inches in thickness.

At the Eckoff well, dug near the middle of section 22, township 49 N., 24 W., the following section was reported:

SECTION XIII.

RECORD OF ECKOFF WELL *(dug)*.

Altitude of top of well about 704 feet A. T.

Interval to top of Lower Coal Measures about 40 feet.	Feet.	Inches.
1. Superficial material	30	
2. Shale and white limestone (?)	25	
3. Shale, *black*	1	
4. COAL		6
Total thickness	56	6

At the Hoelscher well, in the S. W. ¼ of section 15 of the same township, and about a mile northwest of the last, the following section was obtained from the owner of the land:

SECTION XIV.

RECORD OF HOELSCHER WELL *(dug)*.

Altitude of top of well about 770 feet A. T.

	Feet.	Inches.
1. Superficial material	6	
2. Shale, *yellowish*	12	
3. Shale and sandstone, in strata 2 feet thick	7 30	TOP OF LOWER COAL MEASURES.
4. COAL	1	
5. Rock	7	
Total thickness	63	

The bed of coal (No. 4) crops out in the adjacent gullies, and is seen to be of about the thickness given in the well, and

to be overlain by a bed of black, calcareous limestone, some 6 inches thick.

In township 49 N., 25 W., the division line between the Middle and Lower Coal Measures sinks so low topographically as to be very little above the level of the creek bottoms; hence, no exposures exist here from which sections can be constructed. At Aullville, however, within the Middle Coal Measure area, but near its margin, a churn-drill hole was sunk by Messrs. Roberts and Graham to a depth of over 200 feet, of which the following is a copy of the record kept by the drillers and furnished by Mr. Robert Anderson:

SECTION XV. (No. 21 of Section Sheet.)

RECORD OF AULLVILLE DRILL-HOLE.

Altitude of top of well about 720 feet A. T. (at railway level.)

		Feet.	Inches.	
1.	Superficial material	30		
2.	COAL *(probably Mulky bed)*		8	
3.	Sandstone *(probably shale)*	5	6	
4.	Sandstone and shale	4	10	
5.	Shale, *black and blue*	10		TOP OF LOWER COAL MEASURES.
		28		
6.	Limestone and shale	5	6	
7.	Shale	45		
8.	Shale, *bituminous*	2		
9.	Shale	11		
10.	Limestone		8	
11.	Shale	28		
12.	Limestone	4		
13.	Sandstone, *micaceous*	21		
14.	Shale and limestone	6	6	
15.	COAL *(probably Waverly bed)*	2	4	
16.	Shale		8	
	Total thickness	205	8	

THE MIDDLE COAL MEASURES.

The strata of the Middle Coal Measures occupy the greater portion of the area south of the river; they immediately underlie the surface of all the upland country east of the line of the Warrensburg sandstone, and of a few square miles west of that formation. The boundary lines of this formation are so clearly marked on the map that no further description seems necessary here. The dividing line between this group and the

underlying Lower Coal Measures has already been defined; its upper limits are not reached within the sheet, and hence will not be described. The total area represented on the sheet is 148 square miles. The prevailing rocks are shales and limestones, the former predominating; no persistent bed of sandstone is recognized in the section here. The shales are generally argillaceous, and of drab color, sometimes calcareous; near the coal beds they are generally black, bituminous and fissile; they occur in beds ranging in thickness from a few inches to over 30 feet. The limestones are in beds generally from two to six feet thick, but in places some of these beds reach a thickness of as much as 20 feet; they are generally of a very compact and fine texture, in massive beds, of a light drab color, breaking with a semi-conchoidal fracture.

In the sections which have been previously described of the Lower Coal Measures, some Middle Coal Measure beds are also included, as was indicated in each case. In addition, the following sections are given to illustrate the character and the succession of the rocks and to preserve the records that have been obtained at various localities.

Sections along the Missouri river.—In the manuscript notes previously referred to, Mr. Harrison records the following section measured in the bluff about a mile east of Waverly, which probably consists of Middle Coal Measure strata.

SECTION XVI.

BLUFF ABOUT ONE AND A QUARTER MILES EAST OF WAVERLY.

Top of section is about 100 feet above the river bottom (760 feet A. T.)

		Feet.	Inches.
1.	Slope *(soil and Loess)*	20	
2.	Limestone, *bluish, very hard, compact, heavy bedded, uneven surface and fracture*	1	6
3.	Limestone, *bluish, nodular (concretionary), with red, ferruginous and whitish stains. Numerous small masses of Chaetetes milleporaceous in upper part*	2	
4.	Slope, *soil and fragments of yellow, greenish and purple argillaceus shale*	20	
5.	Limestone, *dull blue, hard, compact*	1.	6
6.	Slate, *bituminous or black*	3	
	Total thickness	48	0

The base of the Middle Coal Measures is placed near the bottom of this section.

Beyond this to the west, Lower Coal Measure rocks are exposed which have been described in the preceding pages, the Middle Coal Measure strata occurring near the hilltops. About a mile east of Edwards station the following section was measured:

SECTION XVII.

OUTCROP IN RIVER BLUFF, ONE MILE EAST OF EDWARDS STATION.

Top of section is about 90 feet above the railway.

		Feet.	Inches.
1.	Limestone, *gray*	2	10
2.	Clay, *yellow*		6
3.	Limestone, *blue*	1	
4.	Shale, *buff*	1	3
5.	Limestone, *blue*	2	
6.	Clay, *soft*		6
7.	Limestone	3	
8.	Concealed	1	6
9.	Limestone, *blue*		6
	Interval to base of Middle Coal Measures about 45 feet.		
	Total thickness	13	1

Beyond this again, the Middle Coal Measure strata are confined to the uplands, and only limited exposures of rocks immediately associated with the coal beds were observed. These will be described later under the section devoted to economic geology.

At the mouth of Tabo creek, in the railway cut through the bluffs on the east side, is a small exposure of the basal members of the Middle Coal Measures, illustrated in Detail Section No. 1 of the section sheet; this is bounded on the east by the Warrensburg sandstone. The following section was measured at this point:

SECTION XVIII. (No. 9 of Section Sheet.)

OUTCROP IN RAILWAY CUT AT TABO CREEK.

Top of section is 25 feet above railway (A. T. 710).

		Feet.	Inches.
1.	Limestone, *gray*	2	
2.	Shale, *black*	3	
3.	COAL *(Mulky bed)*	1	
4.	Shale, *argillaceous*	5	
5.	Limestone	4	
6.	Shale, *drab*	10	
	Total thickness	25	

In his manuscript notes, Mr. Harrison gives the following section from the same locality:

SECTION XIX.

SECTION BETWEEN BERLIN AND THE MOUTH OF THE TABO IN SEC. 3.

From Edwin Harrison.

		Feet.	Inches.
1.	Limestone, *hard, bluish gray, compact. Apparently not in place, slidden down*	1	6
2.	Slate, *bituminous; small lenticular concretions*	2	
3.	Slate, *black, tough, compact*	2	3
4.	COAL, *bituminous*	3	
5.	Clay, *blue*	1	
	Total thickness	9	9

About 100 yards below (east of) this, he describes the following section:

SECTION XX.

SECTION AT BERLIN, BELOW TABO CREEK.

From Edwin Harrison.

		Feet.	Inches.
1.	Sandstone, *brownish yellow, yellow and greenish, soft, micaceous, very much washed, uneven bedded; some of the layers heavy bedded, others shaly; containing thin beds of arenaceous shale; concretions of hematite ore. Vegetable remains numerous in some of the beds*	45	
2.	Conglomerate, *hard, silico-calcareous*	3	
3.	Shale, *blue, argillaceous, somewhat arenaceous*	15	
4.	Sandstone, *greenish, shaly*	9	
5.	Shale, *light blue, argillaceous*	2	
6.	Shale, *bluish black, calcareous, containing Myalina and Productus*		6
	Water level of river.		
	Total thickness	74	6

Mr. Harrison does not correlate these two sections, but, in statements elsewhere in his notes, he refers to the sandstone (No. 1, Sec. XX) as the "Micaceous sandstone," which he considers the upper member of the Lower Coal Measure group, and we infer that the members of Section XIX are placed by him geologically above those of No. XX. In the report of the Geological Survey for 1872, G. C. Broadhead quotes the following section from C. J. Norwood, which is in confirmation of this inference:

SECTION XXI.

SECTION AT BERLIN, MADE BY C. J. NORWOOD.

From G. C. Broadhead.

		Feet.	Inches.
1.	Slope, 100 feet at 30°.		
2.	Limestone, *in one bed: ashy blue, argillo-pyritiferous; on the top a thin shelly layer contains fossils, viz.: Bellerophon (2 sp.) large and small, Chonetes, Crinoid stems, Bellerophon Montfortiana, small univalves, etc. Equivalent to No. 32 of the Lexington section (about 30 feet below the Lexington coal bed, A. W.)*	1	2
3.	Shales, *bituminous*	2	

		Feet.	Inches.
4.	Shales, *dark*....	4	
5.	Limestone, *yellowish and bluish drab; top greenish gray; abounds in Ch. mesoloba, and contains a large Productus, also several species of Allorisma*....	2	
6.	Slope....	30	
7.	Sandstone, *generally soft; some parts indurated; mostly drab, some parts with brown specks; plants and Calamites*....	25	
8.	Sandstone, *conglomerate; contains iron concretions and silicified wood, etc*....	5	
9.	Shales, *sandy, green and shaly sandstone*....	14	
10.	Limestone, *shaly, blue, fossils, etc*....	1	
11.	Limestone, *sandy, in thin shaly layers, dark; contains Pr. muricatus*...		6
12.	Slope, *to water of Missouri*....	3	
	Total thickness ...	87	8

Broadhead refers to the sandstone bluffs here as forming bold mural escarpments, and describes the sandstone farther up the river, a mile above the mouth of Tabo creek, as rising about sixty feet. He then gives the following section measured at Tabo bridge, the members of which he considers as probably below the sandstone:

SECTION XXII.

SECTION AT TABO BRIDGE.

From G. C. Broadhead.

		Feet.	Inches.
1.	Bluff.		
2.	Shales, *blue, thinly laminated; with blue calcareous concretions*....	4	
3.	Slate, *black, with thin coal lamina*....	1	
4.	Clay, *blue and gray*....	1	4
5.	Coal, *bituminous*....		2
6.	Clay, *blue, thinly laminated; bearing a two-inch band of iron-stone midway and also small crystals of selenite*....	18	
7.	Limestone, *shaly; deep ashy blue; containing P. muricatus*	?	
8.	Shales, *clayey, to the water in the creek*....	14	
	Total thickness....	38+?	6

The difference between the last section and the lower members of Section XXI, notwithstanding the fact that they are from closely adjoining localities and are taken from the same altitude, suggests something abnormal, and this is strengthened by the differences between these sections and Nos. XIX and XX. The reasons for these discrepancies will be discussed later, when the Warrensburg sandstone is described. Suffice it here merely to call attention to their existence.

Sections between the Missouri river and the Chicago and Alton railway.—Over the uplands immediately south of the river, the thick mantle of the Loess covers the rock so effectively

that no continuous exposures are found from which sections can be measured. A number of wells and drill-holes have been put down here, but no complete records could be obtained of these.

The Davis well, in section 29, township 51 N., 24 W., about three miles southwest of Waverly, is near the hill-top and was sunk to a depth of 110 feet. The drillers were interviewed concerning this well, and reported that no coal was encountered, and that soil and clay were found to a depth of 60 feet, and under this 50 feet of sand were penetrated. This would indicate a very abnormal depth of superficial material; but the results are explicable on the hypothesis that a buried channel occurs here, now filled with drift and covered with Loess. Should the lower 50 feet be sandstone in place of sand, as reported, we should be inclined to consider it a sandstone channel deposit, tributary to the Warrensburg sandstone, later to be described. In this case the sandstone of Davis quarry and adjacent localities, described on pp. would be assignable to this horizon.

The Slusher well, about two miles southwest of the last, in section 36, township 51 N., 25 W., is 40 feet deep, but no information could be obtained concerning it, other than that no coal was encountered.

The Phillips well, about three miles northwest of Slusher's, in section 27 of the same township, is over 100 feet deep. No record could be secured, but Mr. Phillips, the owner, furnished the information that two beds of coal were encountered, as follows:

1. At a depth of 60 feet.....24 inches of coal,
2. " " " 100 feet.....22 " "

The upper of these we correlate with the Lexington bed, the lower with the Mulky bed or with that exposed at the mouth of Tabo creek, No. 3 of Sec. XVIII.

The Catron well, south of Salt creek, in section 4 of township 50 N., 24 W., passes through some of the lower members of the Middle Coal Measures. A copy of the record is given on p. 31 of this report.

The Larkin well, in section 6 of the same township, furnishes no facts other than that no coal was found, and that quicksand was encountered at a depth of 55 feet. The occurrence of the sand here adds additional weight to the report of the existence of a large body of sand below 60 feet in the Davis well, two miles north.

Along the western line of township 50 N., 24 W., the Lexington coal bed crops out and has been operated at the Lewis pits, in section 18. About a mile east of this it was also encountered in the Rogge well. Across Salt creek from this well, near the foot of the hill, Harrison measured the following section:*

SECTION XXIV.

ON EAST SIDE OF SALT FORK, IN SECTION 17, S. W. ¼ OF N. E. ¼.

From Edwin Harrison.

		Feet.	Inches.
1.	Shale, *yellow, argillaceous*	2	
2.	Shale, *yellow, argillo-calcareous, containing numerous Chonetes mesoloba.*	1	9
3.	Limestone, *argillaceous; yellow or greenish; weathered surface soft and yellow, compact, smooth fracture, Fusulina, Crinoid stems*	2	3
4.	Limestone, *yellow, argillaceous, in uneven layers, separated by seams of yellow shale*		6
5.	Shale, *yellow, argillaceous*		3
6.	Shale, *bluish black, argillaceous; containing numerous small lenticular concretions, and a few large globular ones toward the bottom*	3	9
7.	Clay, *light blue to water level*		6+
	Total thickness	11	0

The limestone of the section he correlates with a heavy bed of limestone which occurs at Lexington, about forty feet below the Lexington coal bed. This correlation is supported by the results of recent work.

In the adjoining section 18, he describes the following:

SECTION XXV.

WEST OF SALT FORK, IN SECTION 18, N. E. ¼ OF S. W. ¼.

From Edwin Harrison.

		Feet.	Inches.
1.	Limestone, *blue, fine grained, heavy bedded, smooth fracture, Fusulina*	2	
2.	Slope, soil	10	
3.	Limestone, *bluish and yellowish: concretionary, upper part disintegrating into small nodules, containing numerous Chaetetes milleporaceus, Fusulina cylindrica. Smooth fracture, small cavities filled with a yellow substance—(Sesquioxide of iron?)*	1	
4.	Limestone *blue, coarse grained uniform texture, thin bedded*	1	
5.	Shale, *blue, argillaceous, interstratified with yellow seams of sandy shale*		6
	Total thickness	14	6

*MS. notes, p. 14.

The top of this section, Harrison places at 60 or 70 feet above the Salt fork. According to this it must commence close under the Lexington coal bed, and all of its members would belong to the Middle Coal Measures.

No other records were obtainable in township 50 N., 24 W. The Fletcher, Goodwin, Metcalf and Barnett wells, located on the map, yielded no facts excepting such as are there noted. A great thickness of superficial material covers that portion of this township lying south and east of Salt creek, and exposures are entirely absent, and only very deep wells reach the underlying rock.

In township 50 N., 25 W., north of the Chicago and Alton railway, similar conditions prevail, although the superficial covering is not so deep.

The Corder Coal Company's Shaft, in section 27, just west of the town of Corder, is 96 feet deep. At the bottom of this shaft a churn-drill hole was put down some 230 feet farther, making the total depth penetrated by shaft and drill-hole about 330 feet. The following record was furnished by Mr. David Hoffman, by whom the drill-hole was sunk:

SECTION XXVI. (No. 14 of Section Sheet.)

RECORD OF CORDER SHAFT AND DRILL-HOLE.

Top of shaft is at an altitude of about 885 feet A. T.

		Feet.	Inches.
	SHAFT.		
1.	Soil	5	
2.	Superficial material and shale, *white and gray*	35	
3.	Limestone, *reddish, hard*	5	
4.	COAL		6
5.	Fire-clay	4	
6.	Shale	4	6
7.	COAL, "*bony*" *and pyritiferous*		10
8.	Shale, *blue*	18	
9.	Limestone	22	
10.	Shale, *black, fissile*	1	6
11.	COAL *(Lexington bed)*	1	8
	DRILL-HOLE.		
12.	Fire-clay		10
13.	Limestone	6	
14.	Shale, *white and gray*	15	
15.	Shale, *blue*	2	4
16.	Shale, *white*	18	
17.	Limestone, *blue*	1	3
18.	Shale, *black*	2	6
19.	Fire-clay		6

		Feet.	Inches.
20.	Limestone		4
21.	Shale, *gray (horizon Mulky coal bed)*	7	
22.	Rock *(hard, not affected by acid)*	3	
23.	Rock, *softer*	3	
24.	Shale, *gray*	8	
25.	Shale, *red*	4	
26.	Shale, *gray*	2	
	TOP OF LOWER COAL MEASURES (Depth 171 feet 9 inches).		
27.	Limestone, *not very hard (probably sandstone, A. W.)*	23	6
28.	Fire-clay, *blue*		4
29.	Shale, *nodular*	6	2
30.	Shale, *gray*	30	
31.	Shale, *white*	3	3
32.	Shale, *yellow*	4	
33.	Limestone		10
34.	Shale, *gray, hard*	8	
35.	Shale, *gray*	4	
36.	Sandstone		11
37.	Fire-clay		8
38.	Ferruginous band		8
39.	Shale, *gray, hard*	1	6
40.	Limestone, *yellow*		5
41.	Shale, *black, fissile*		7
42.	COAL		10
43.	Shale	1	10
44.	Limestone, *hard*		4
45.	Shale, *intercalated with layers of limestone about 1" thick, at interrals*	8	2
46.	Shale, *blue*	4	10
47.	Limestone, *blue*	1	6
48.	Shale, *hard, blue*	4	
49.	Limestone, *blue, very hard*	19	2
50.	Shale, *dark blue*		11
51.	Shale, *gray and blue*	2	
52.	COAL		5
53.	Fire-clay	1	8
54.	Pyritiferous rock	1	3
55.	Shale, *light blue*	5	
56.	Limestone, *blue, hard*	15	
57.	Shale, *dark blue, with black streaks*	5	6
58.	Limestone, *reddish*		11
	Total thickness	329	11

The results expressed in this record must be accepted with allowances, both as to the thickness as well as to the character of the various strata. Over and above the inaccuracies inherent in results derived from the churn drill, we are inclined to think that much of what is termed limestone in the lower and central part of the hole is largely sandstone or compact shale, possibly calcareous. We are led to this conclusion by knowing of instances in the region where drill and shaft men have termed compact sandstone and hard shale a limestone, and, further, through

the knowledge of the existence of sandstones and tough sandy shales at corresponding horizons along the river. A study of the Lower Coal Measure sections given on previous pages will reveal this.

The Winsor Shaft is about three miles west of Corder, just south of the railway track. This shaft is now abandoned, and the following record was obtained from Capt. Smith, of Corder:

SECTION XXVII. (No. 15 of Section Sheet.)

RECORD OF WINSOR SHAFT, WEST OF CORDER.

Top of shaft is at an altitude of about 860 feet A. T.

		Feet.	Inches.
1.	Soil and clay	16	
2.	Limestone, *white*	4	
3.	Shale, *blue*	4	
4.	Limestone, *blue*	1	6
5.	Clay	8	
6.	Limestone, *blue, compact*	9	
7.	Shale	1	
8.	COAL	1	8
9.	Clay	1	
10.	Limestone	6	
Interval to *base of Middle Coal Measures about 70 feet.*			
	Total thickness	52	2

The Bonanza Coal Company's shaft is about a half a mile beyond the Winsor shaft to the west, and is also on the Alton railway. This shaft is still in operation. The following record was furnished by Mr. Brandeau, the owner of the mine, but the coal and associated strata were measured by Mr. Gluck:

SECTION XXVIII.

RECORD OF BONANZA COAL CO.'S SHAFT, WEST OF CORDER.

Top of shaft is at an altitude of about 880 feet A. T.

		Feet.	Inches.
1.	Soil	18	
2.	Shale	17	
3.	Limestone	6	
4.	Shale, *with limestone intercalated in layers about 8 in. thick*	8	
5.	Limestone, *hard*	6	
6.	Shale, *black, fissile*	1	6
7.	COAL	1	8
8.	Clay		8
Interval to base of Middle Coal Measure about 80 feet.			
	Total thickness	58	10

North of this, in the same township, we have no records other than extremely short ones including a few strata immediately associated with the coal beds. These will be described later under the division of Economic Geology.

South of the Chicago and Alton railway, between it and Davis creek, the Middle Coal Measure rocks extend from a short distance above the waters of that creek to the summits of the hills. Only a few sections were obtained here, however, over and above those of coal beds and the immediately associated rocks.

In the railway cut near the hill summit, about a mile southeast of Aullville, Broadhead gives the following section:*

SECTION XXIX.

SECTION IN RAILWAY CUT SOUTHEAST OF AULLVILLE. (From Broadhead.)

Top of section is at an altitude of about 800 feet A. T.

		Feet.	Inches.
1.	Clay.		
2.	Limestone, *in irregular beds*	3	
3.	Shale, *bituminous*	2	6
4.	Shale, *sandy and ochrey*		5
5.	Coal, *impure* } Lexington bed		4
6.	Coal, *good* } Lexington bed		12
7.	Clay, *black, with plant remains and selenite crystals*		6
8.	Clay, *blue, fossiliferous, with P. costatus and Athyris subtilita*		5
9.	Clay, *blue*	3	
10.	Limestone, *gray, thick bedded, rough; in the upper part it abounds, in Fusulina cylindrica, also contains Pleurotomaria, Athyris and Crinoid stems; and minute dolomite crystals. This limestone is probably hydraulic.*	6	10
	Total thickness	18	0

The recent observations of the Survey since made at this locality confirm the accuracy of this section.

West of this cut the country sinks rapidly and the base of the Middle Coal Measures is not far beneath the surface. In the drill-hole sunk at Aullville, of which the record is given as Section XV, a few of the lower members are included.

About a mile west of Aullville, at the foot of the hills, on the edge of the Davis creek alluvial plain, a drill-hole was put down by Messrs. Roberts and Parker, of which the following is a record, as obtained from the driller's notes:

* Report Missouri Geological Survey, 1872, Part II, p. 46.

SECTION XXX. (No. 22 of Section Sheet.)

RECORD OF ROBERTS AND PARKER DRILL-HOLE.

Altitude of top of drill-hole is about 720 feet A. T.

		Feet.	Inches.
1.	Soil and clay	19	
2.	Sandstone		6
3.	Shale, *micaceous*	8	
4.	Limestone, *shaly*		4
5.	Shale, *argillaceous*	10	
6.	COAL		3
7.	Shale	1	
8.	Limestone	2	
9.	Shale	2	6
10.	Limestone		6
11.	Shale, *black, fissile*	1	6
12.	COAL *(Mulky bed)*	1	6
13.	Fire-clay		6
14.	Shale, *argillaceous*	3	6
15.	Sandstone	5	
16.	Shale	6	
Base of Middle Coal Measures about here.			
	Total thickness	62	1

Immediately west of this drill-hole the country is occupied by the Warrensburg sandstone for a distance of between one and two miles. West of this area we again pass into the Upper Coal Measures which are exposed and penetrated by shafts along Rocky branch, west of Higginsville. The following section of one of the shafts from this vicinity will suffice to show the succession of rocks there:

SECTION XXXI. (No. 20 of Section Sheet.)

HAWKINS AND SMITH SHAFT.

Altitude of top of shaft is about 870 feet A. T.

		Feet.	Inches.
1.	Soil and clay	23	
2.	Shale	40	
3.	Limestone	16	
4.	Shale, *black, fissile*	1	8
5	COAL *(Lexington bed)*	1	6
6.	Clay	2	6
7.	Limestone	7	4
8.	Clay, *shaly*	16	
Interval to base of Middle Coal Measures 25 or more feet.			
	Total thickness	108	0

THE WARRENSBURG SANDSTONE.

The Warrensburg sandstone occupies the western portion of the sheet; the total area represented is about 39 square miles. It derives its name from the town of Warrensburg, a few miles south, in Johnson county, where this formation attains a great development. It consists of a great body of sandstone, changing irregularly into shale and shaly sandstone, with no coal or limestone beds interstratified. Its relations to the surrounding Coal Measures is peculiar; it does not overlie these strata, but cuts across them, apparently occupying a depression which once existed where the sandstone now is. The north-most exposure of this formation is at the mouth of Tabo creek, on the Missouri river. Reference to sandstone at this point has already been made (page 36), and its lithological characteristics are well described in Sec. XX and in Sec. XXI on page 36. Certain discrepancies in these sections are alluded to on this page. They arise partly from the fact that Sec. XXI is undoubtedly not a continuous section, and must have been compiled from measurements made at different points. We maintain that the coal and limestone do not *overlie* the great body of sandstone developed at the mouth of Tabo, but they are both at the same level. This relationship is well displayed in the railway cut at the mouth of Tabo and is illustrated in the cross section sketch entitled, Detail Section No. 1, on the section sheet. In the horizontal extension of the coal and limestone strata at the west end of the sketch, is a large exposure of arenaceous, micaceous shale of the Warrensburg sandstone. The approximate position of the line of contact is indicated on the sketch. The down curving of the heavy bed of limestone near the base may be attributed to a settling or "creeping" of this rock down the side of the hollow before the sandstone was deposited. The coal and limestone outcrop is close to the mouth of Tabo creek, on the east bank. West of the creek the sandstone occurs again in the bluffs. This limestone and coal exposure of the Middle Coal

Measures is, hence, of the nature of an island, or possibly of a peninsular surrounded by these arenaceous deposits.

North of the Missouri the exact outline of the formation cannot be defined, inasmuch as all exposures are hidden under the alluvial deposits of the river.

South from the river the limits are traced, on the one side, by well records in the sandstone and surface exposures of that rock; and, on the other side, by exposures of limestone and coal, or openings in the last. The distribution of such exposures and openings is clearly shown on the large map.

The Dinwiddee well in Dover, was drilled to a depth of 80 feet, of which the upper 60 feet were in soil and clay and the lower 20 feet in sandstone.

West and southeast of Dover are several exposures of sandstone which are located on the map, and which are described by Mr. Gilbert Van Ingen as follows:

On the western edge of the town, in the northeastern quarter of section 30, he finds 15 feet of non-fossiliferous, yellowish, gray, disintegrated, micaceous sandstone. This is not far north of the Dinwiddee well and, by reference to the topographic map, it will be seen that such an outcrop here must be about the 800 feet contour line. The altitude of the Lexington coal bed in adjacent sections is about 760 feet; hence this sandstone occupies the hypsometric position of the strata overlying this coal.

In the northeastern quarter of section 20, northeast of the town, he reports 20 feet of the same sandstone; and in the northeastern quarter of section 32 he locates another outcrop.

*The Hutchison** well (40 feet deep), north of Dover, in section 13, township 50 N., 26 W., is only 40 feet deep, and is chiefly in superficial material. Sandstone was encountered here near the bottom of the hole. The altitude of the top of the well is about 800 feet A. T.; while that of the Lexington coal bed, less than two miles to the east, is about 780 feet.

*The information concerning the results obtained by drilling at this point, as well as at others in this sandstone belt, hereinafter cited, was kindly furnished by Messrs. Newland and George, well drillers of Higginsville, Mo.

Hence the bottom of the hole is below the level of the coal, though the sandstone is not quite that high.

The Petticorn well (churn drill hole, 700 feet deep), about a mile and a half southeast of Page City, in the northeastern corner of section 25, township 50 N., 26 W., is currently reported to be about 700 feet deep. No record could be obtained of the hole other than that no coal was encountered and that shale and sandstone were penetrated. The top of this well is about at the altitude of the Lexington coal in the adjacent country.

The Hoehn well (churn-drill hole, 155 feet deep) is about half mile east of the Petticorn, in section 30 of township 50 N., 25 W. Here about 30 feet of soil and clay were first passed through, and these were followed by 125 feet of sandy shale, growing less sandy with increased depth and containing a few seams of flaky limestone. The altitude of the top of this hole is about 840 feet, and the sandy shales hence occupy the position of the Lexington coal bed which occurs in the section immediately north. This hole is near the marginal line of the formation, and we might hence expect the material to be somewhat of a transitional nature, as the record suggests.

The Grove Young well (churn-drill hole, 76 feet deep), is about half a mile southwest of the Petticorn, and in the same section. Two holes have been put down here recently, close together. In one, about 16 feet of superficial material was first encountered and then some 60 feet of sandy shale grading into argillaceous shale; in the other about 16 feet of superficial material was also encounted, and then 60 feet of sandstone was passed through. The altitudes of the tops of these wells are about 820 A. T. Hence the sandstone is well above the horizon of the Lexington coal bed. The difference in the records furnishes an illustration of extreme variability in the stratification of this arenaceous formation.

The McCausland well (churn-drill hole, 1,000 feet deep), is located in the immediate vicinity of those last described. This well is currently reported to have been 1,000 feet deep. Broad-

head refers to this well in a previous report of the survey* and states that the borings extended to a depth of 800 feet. The sandstone cropping out here he describes as oily and bituminous; the drilling was prosecuted in the hope of discovering oil, but no considerable quantity was obtained.

The Fulkerson well (churn-drill hole, 135 feet deep), is in section 26, about a mile west of Grove Young's. No coal was encountered, but arenaceous and argillaceous shales were passed through. The top of this well is only about 720 feet A. T., and is, hence, well below the Lexington coal bed. That none of the lower strata was encountered indicates, however, the extension of the Warresburg sandstone this far.

The Nolting well (No. 18 of section sheet, churn-drill hole, 170 feet deep), is less than a mile north of Higginsville. Here a well 30 feet was first dug and then a drill-hole was put down to a depth of 140 feet, passing through sandy shales, which became compacter and more sandy toward the bottom. The altitude of the top of the hole is about 830 or 840 feet A. T., or 50 to 60 feet above the Lexington coal bed.

The Oundiff well (churn-drill hole, 44 feet deep), is on the northern edge of the town of Higginsville, about half a mile south of the Nolting well. Here 17 feet of soil and clay were passed through, and then 27 feet of sandy shale. The altitude of the top of the well is about 850 feet A. T.

Within the limits of the town of Higginsville a number of drill-holes have been put down which are perfectly accordant in showing the presence of a great body of sandstone here.

The City Mills well (churn-drill hole, 250 feet deep), is near the Chicago & Alton railway depot. Here 40 feet of superficial material was first passed through, then 150 feet of arenaceous shale. Coal is reported to have been encountered at a depth of 250 feet, but it is not thought to represent a regular bed. The altitude of the top of this well is about 840 feet A. T., or about 60 feet above the Lexington coal bed.

In the Cannery well (churn-drill hole 60 feet deep), on the Missouri Pacific railway, at the southern edge of town, 23 feet

*Report Mo. Geological Survey, 1872, Part II, p. 41.

of soil, clay and "gravel" were first encountered, followed by 37 feet of hard, reddish sandstone. The altitude of the top of the well is about 820 feet A. T.

In Bird & Co's well, south of the last, and in the *Grove well* north of it, very similar results were reached.

The Riggs & Hoeffer well (churn-drill hole, 155 feet deep), is immediately north of the Grove well. About 30 feet of soil and clay were first encountered and then about 125 feet of sandy shale, passing into sandstone, was penetrated. The altitude of the top of the well is about 840 feet A. T.

Asbury & Co's well (churn-drill hole, 155 feet deep), is about a quarter of a mile southeast of the town, and south of the Chicago & Alton railway. Superficial material was passed through to a depth of 25 feet, and then 60 feet of sandy shale. The altitude of the top of the well is about 840 feet A. T.

Two other drill-holes in this formation in Higginsville, the Dooly and Anderson wells, are plotted in the section sheet, under numbers 17 and 19 respectively.

Along the branch flowing south from Higginsville, are numerous exposures of the Warrensburg sandstone. Some of these are located on the map. At one of these, in the S. E. quarter of section 6, township 49 N., 25 W., the following detailed section was measured by Mr. Van Ingen. It well illustrates the lithologic characteristics of this formation.

SECTION XXXII.

DETAILS OF WARRENSBURG SANDSTONE AT HIGGINSVILLE.

		Feet.	Inches.
1.	Clay		3
2.	Sandstone blocks, *red brown, lying loose in the clay*		4
3.	Clay, *yellow*	1	6
4.	Sandstone, *dark chocolate, with iron clay nodules and plant remains*		6
5.	Sandstone, *gray brown; very irregularly bedded*		6
6.	Ocher bed, *red; with iron clay nodules, bits of wood, a few Brachiopoda and a Crinoid stem*		4
7.	Sandstone, *gray, yellow; some thin dark layers in lower portion; are horizontal for a few feet and then carve upwards and have gray layers intercalated*	1	
8.	Sandstone, *gray, micaceous, no fossils; unconformable upon the next stratum*	2	
9.	Sandstone, *brown, has an apparent stratification caused by thin intercalated bands of red brown sandstone; micaceous, no fossils*	3	
	Total thickness	12	2

The stratification, Mr. Van Ingen notes, is very local. The sandstone appears along the branch, a quarter of a mile farther south and extends half a mile beyond. Here there is no stratification that extends a distance of more than five feet.

About a mile south of this point, near the north line of section 18, between the county road on the west and the railway on the east, are exposures in the creek bank of this sandstone ten and fifteen feet thick. Both massive and thinly bedded layers are shown here. The accompanying figure 5 (plate iii) illustrates one of these exposures.

South of Higginsville the course of the Warrensburg sandstone is further well defined by a series of wells.

The Ayres well (No. 28 section sheet, churn-drill hole, 130 feet deep) is near the middle of the west line of section 24, township 49 N., 26 W. Here, after passing through 30 feet of soil, about 100 feet of sandstone was penetrated. In another well on the Ayres property, about half a mile south of the last, similar results were obtained. The altitudes of the tops of both of these wells is about 825 feet A. T. That of the Lexington coal bed, two miles east, is about 780 feet.

The Higgins place is about half a mile east of Ayres'. Here two wells have been drilled, 150 and 200 feet deep respectively. In the first, 26 feet of soil and clay were passed through and then 125 feet of sandstone. In the second (No. 27 of section sheet), after penetrating 30 feet of soil and clay, a stratum of sandstone, 2 to 3 feet thick, was encountered and then 167 feet of sandy shales with thin layers of flaky limestone. The tops of both these holes are at an altitude of about 760 feet, and consequently below the altitude of the Lexington coal bed.

The Wedge well (dug well 50 feet deep) is about three-fourths of a mile east of the Higgins place. It is just on the margin of the formation and the record of the well indicates this. The entire well was in sand and clay, with shale and limestone at irregular intervals. The altitude of the top of the well is about 760 feet A. T.

The Gladdish well (churn-drill hole, 69 feet deep) is about a mile south of the Ayres well, near the southern part of section

26. Here about 30 feet of superficial material was passed through and then 39 feet of sandstone. The altitude of the top of the well is about 860 feet A. T., and that of the Lexington coal bed in a closely adjoining shaft is about 800 feet.

The sandstone which we designate the Warrensburg formation, has been observed during the progress of earlier surveys and is referred to in the earlier reports. Extracts from such references have been made on preceding pages of this report. Swallow, in his Second Annual Report,* describes as the upper member of the "Lower Coal Series," a "soft, brown, heavy bedded, irregularly stratified micaceous sandstone," appearing at Dover among other places. Broadhead describes this sandstone in the report for 1872,† and correlates it with sandstones near Butler in Bates county, on Sugar creek, in Cass, at Warrensburg in Johnson, at White rock in Carroll and on Grande river in Chariton county. All of these outcrops he assigns to the Lower Coal Measure formation.‡

The true stratigraphic and structural relations of this formation, however, seems not to have been recognized. It appears generally to have been considered of Lower Coal Measure age, and to have been correlated with the inter-stratified sandstones of the Lower Coal Measures, referred to on other pages of this report. The peculiar conditions of occurrence of this formation have, however, received no satisfactory explanation in print, to the writer's knowledge. ||

The theory here advanced concerning this deposit is that it is of fluvial or lacustrine origin, that it fills a channel which was eroded in the surrounding, regularly deposited strata, during a temporary emergence of these strata from beneath the waters of the Coal Measure swamp. The leading reasons for this conclusion are, briefly, the following:

* Report Missouri Geological Survey, 1855, part 1, p. 85.

† Report Mo. Geological Survey, 1872, Part II, pp. 41, 42, 43, 44.

‡ *Ibid*, p. 42.

|| In a letter to the writer of Feb. 1890, Prof. Broadhead explains the peculiar altitude or position of the sandstone in Lafayette county as due to a bulging of the Lower Coal Measures, and this was probably the explanation accepted by the earlier surveys. In more recent writings Prof. Broadhead abandons the older view in the light of this later acquired evidence.

1. The great thickness of the deposit;

2. Its long and narrow shape;

3. The superposition of the sandstone upon the Middle Coal Measnre rocks;

4. The inclusion of fragments of adjacent rocks.

1. The exact maximum thickness of the Warrensburg sandstone is impossible to determine with the data at hand. The results of the drillings already cited would indicate, however, that it is at least as much as 200 feet. The Petticorn and McCausland wells (see p. 47) would seem, on account of their great depths, to offer opportunities for a settlement of the questions. Nothing that can be called a record of these holes could be obtained, however, and, from the fragmentary notes which were collected, it is impossible to say just where the lower limits of this formation were reached, and to what extent the shaly and arenaceous strata of the Lower Coal Measures were penetrated. The indefiniteness as to the depths of this formation is indicated by the irregular termination of the pattern in the section sheet.

The idea that the deposit is as much as 700 or 800 feet thick seems too extravagant to be accepted, without the most convincing evidence. In fact, if these holes reached any such depths we are inclined to think that they entered the strata of the Lower Carboniferous series.

At points near the margin, limestones are encountered under the sandstones at depths dependent upon the nearness of the excavation to the margin, and at low points within the area of the formation, outcrops of limestone are exposed by the erosion of the overlying sandstone. Such an outcrop is the one at the mouth of Tabo creek, and also the one located on the map in section 11, township 50 N., 26 W.

2. This long and comparatively narrow shape of the deposit is shown on the map. Particularly in the southern portion has it these characteristics, toward the north it seems to spread out in a more estuary-like form. The lateral limits are defined by outcrops and the results of drilling, such as have been de-

scribed, and the fact that the coals and associated strata of the adjacent area terminate abruptly at the marginal line is abundantly proven.

3. The superposition of the sandstone upon the Middle Coal Measure rocks is indicated by the fact that the sandstone is not encountered under the strata of that formation in shafts and drill holes, even when the latter are close to the margin of the sandstone; this would not be the case did this sandstone underlie those strata. Further, the contact between the two formations, exposed at the mouth of Tabo creek, displays plainly this relationship, and similar contacts have been observed at other localities not included on the sheet.

4. The inclusion of fragments of the adjacent strata in the sandstone, and the formation of a breccia or conglomerate of such are phenomena which were not observed by the writer within this area, but Norwood's reference to such on p. 37 of this report demonstrates their existence. South of the area, however, in the vicinity of Warrensburg, such have been found at several points by the writer, the fragments consisting of limestone, shale, clay iron-stone and coal.

A study of the descriptions of sections already given will reveal the lithologic character of this formation. It is a soft sandstone, always micaceous, generally very friable, frequently excessively false bedded, grading rapidly into arenaceous shale, almost always ferruginous and of yellow and brown colors. It seldom has sufficient coherence to be of value for structural purposes especially within this sheet, in fact it is sometimes so soft as to be excavated with pick and shovel. In the neighborhood of Warrensburg and at other points in the State it becomes locally more coherent and is extensively quarried for building purposes; it is there also of a gray, or faintly yellow color, containing much less iron than at other points.

The outlines of the formation given on the map are to be taken only as approximate. Great exactness can, from the nature of the case, not be expected. It is to be anticipated that the deposition of the sandy material was not confined entirely to the main channel, but that there were tributary chan-

nels, and thus that tongue-like lateral extensions of the formation once existed. These are probably in part removed by erosion, in part remained concealed. The outcrops of sandstone in section 18 of township 51 N., 24 W., and of section 16 of township 49 N., 25 W., we are inclined to attribute to such an origin. The extension of the formation under the alluvial plain north of the Missouri river is hypothetically and provisionally represented. That it is connected with similar deposits exposed in Carroll and Ray counties we have good reason to believe, but we are not yet prepared to define the exact line of connection.

THE QUATERNARY GEOLOGY.

BY J. E. TODD.

The superficial geology of the region under consideration is usually simple. Traces of the great ice invasion are very slight, and are limited to the extreme northern border. The high terraces of more recent times are not conspicuous and bottom lands are not extensive in the region. The yellow loam, known as Loess, or the "Bluff Deposit," covers almost the whole surface like a blanket.

Named in chronological order, the quaternary formations found here are as follows:

1. THE DRIFT.
2. THE LOESS, OR UPLAND LOAM.
3. THE TERRACES.
4. THE BOTTOMS.

We will consider them in this order, or from the oldest to the most recent. Their distribution is shown on the following sketch map:

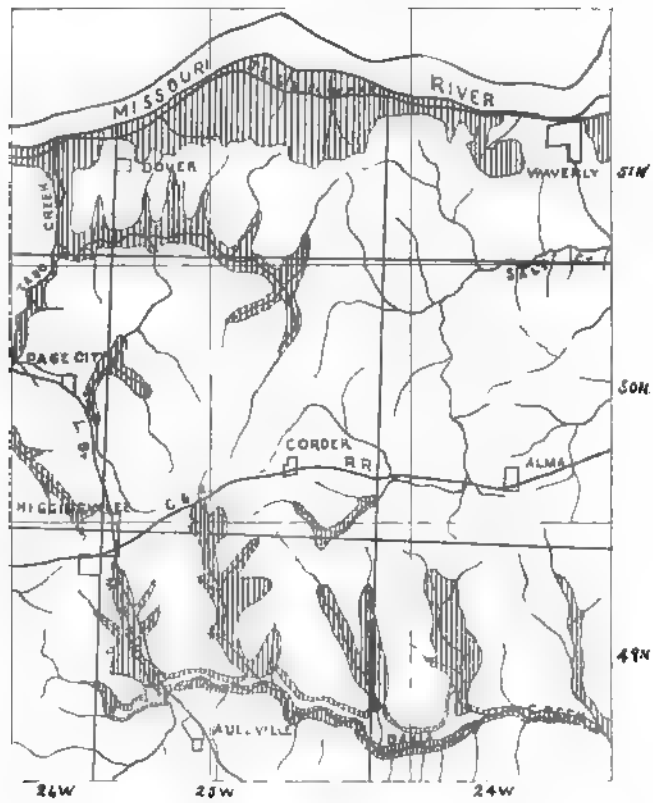

Fig. 6 Outline map showing the distribution of Quarternary formations within the Higginsville sheet

The Drift. This formation is but feebly developed, yet it presents most of the characters commonly found in it elsewhere. It consists of a confused mass of crystalline boulders and pebbles of northern origin, mingled with sand or embedded in a yellowish brown clay. The formation has been found only along the bluffs fronting the Missouri, and from fifty to seventy feet above low water. It is rarely over three feet thick and rests upon the surface of the Carboniferous rocks below, with

the loose blocks of which it is more or less commingled. The boulders of granite, greenstone and red quartzite frequently show distinctly planed and striated surfaces.

No blue till has been found, nor should we expect it in so shallow a deposit. No striated ledges have been found, yet it is not improbable that they occur. In a deep ravine near the railroad, a little west of Waverly, several large blocks of limestone were found not far apart with one side planed and deeply striated, as though they might have come from such a ledge not far away.

No evidence has been found in wells which would seem to indicate the existence of drift back from the Missouri. Moreover, the common occurrence of Carboniferous strata over most of the region at from 75 to 100 feet higher than the drift exposures already mentioned almost demonstrates that such is not the case. The drift is everywhere overlain with deep loess.

The Loess. This formation is the principal geological feature of the region. The beauty of the landscape and the fertility of the soil are directly traceable to it. It is a loam, usually of a pale, brownish-yellow tint, sometimes bordering on ash, but more frequently, in this county, it is of a redder cast than the typical variety. It seems also to be generally of a somewhat looser texture than the average, less inclined to show natural surface of vertical cleavage, more inclined to wash on steep hill-sides. In lower exposures it has been noticed to contain numerous small black concretions, which indicate, more iron than is usually found in it elsewhere. Calcareous concretions on the other hand, seem not so common as in many other localities. It contains no pebbles, especially in its upper portions. No fossils have been noted except a few fragile land snails.

Where it rests upon Carboniferous sandstone or shale, it is sometimes more or less mixed with them for a few feet. When it overlies drift it becomes more clayey below and of a darker and redder tint.

FIG. 5 A VIEW OF THE WARRENSBURG SANDSTONE AS EXPOSED SOUTH OF HIGGINSVILLE

FIG. 7 VIEW OF LOESS ALONG THE ROAD CUT THROUGH THE RIVER BLUFF AT WAVERLY

It has not been found to rise higher than an altitude of 900 feet above the sea, in the region under consideration. There are three areas in this elevation; two near the Missouri, in township 51 N., 25 W., and one west of Corder. This level corresponds with the altitude of the edge of the loess plain near Mayview.

The thickness of this formation, as near as can be judged from reports of wells and coal shafts, is very rarely over 50 feet on the uplands, and is sometimes not more than 15 or 20. Near the Missouri it is sometimes over 100 feet in thickness. The differences in thickness and in the altitude of the general surface of the little eroded uplands, are traceable to the unevenness of the underlying formations. An instructive view of the loess as developed along the river at Waverly is shown in figure 7 (plate iii.)

The topography of the country is largely influenced by certain characteristics of the loess, which are brought out in its erosion. At first recession of the waters which deposited it, the surface loess, we conceive, was a quite even and almost level plain. Perhaps there were differences in level of a hundred feet in our area, but probably not so great by half. The present streams beginning upon this plain ere long cut down through the loess and into the underlying sandstones and clays. This continued until a base-level of about 700 feet was reached, as has been done by all the streams showing bottoms along their courses. This level is nearly 200 feet below the original plain. In many regions this could not have been done without many cliffs and broken areas being produced too rough for tillage. But in this loess-covered region such features are almost unknown. Everywhere beautifully smooth surfaces and gentle curves adorn the landscape. This effect results from a kind of plasticity in the loess which is traceable to the way it yields to degradation. This degradation is accomplished by subterranean waters, surface waters and winds. The first softens the underlying clays, or frequently the lower part of the loess itself. Then the proneness of the loess to break into columnar portions by cracking vertically, allows each column to push

its softened base down and out. In this way cliffs and steep banks gradually change to a succession of steps. Rains loosen the surface portions and wash them into the crevices and tend to fill slight depressions, unless they collect into rills. In the latter case they begin a furrow which may soon become a gully. But the sides of this again will, in time, be gently sloped.

Winds also play an important part in shaping the loess, especially in smoothing it and giving it a rounded outline. The fine particles loosed by frost or drouth are swept like the snow. This influence is rarely marked, but in a great length of time doubtless amounts to considerable.

The result is that the loess has crept down and thickly covered all slopes, some of them many feet below its original base, so that it may often seem to a superficial observer to be from 150 to 200 feet thick. This tendency of the loess is of great value to the farmer, for it furnishes a valuable subsoil over the whole region. By reason of its porosity it quickly absorbs the rain, yet it prevents excess of moisture by natural underdrainage. It furnishes a happy medium between clay and sand, is most easily tilled in either wet or dry seasons.

It follows from the above that the loess, as found in valleys and on the lower hillsides, is rarely in its true relation to underlying formations and is apt to be mingled with them. The more instructive sections are to be sought therefore on the uplands.

The Terrace. There is found along the Missouri river at several points in the State a high terrace rising 100 to 125 feet above the stream. No trace of this has been found in eastern Lafayette county, along that stream, but west of Tabo creek a portion appears on our map of quite an extensive terrace rising 60 to 80 feet above the river. Its structure has not been closely studied, but in a general view of the valley it is quite noticeable. It is much eroded.

The Bottoms. Under this head we include both the "Alluvium" and "Bottom Prairie" of Swallow. They have all been formed by the present streams flowing at their present level.

The only difference between the classes mentioned in earlier reports seem to be one of age. The bottoms are noticeable along Davis, Salt and Tabo creeks, sometimes attaining a breadth of half or three-fourths of a mile. Along the Missouri very little bottom land is found in this county, although it is very wide on the north side. Everywhere these lands are rich and valuable, excepting in limited portions which are marshy.

Opportunity has not been found to examine exhaustively the whole area under consideration. There is room for further discoveries concerning the Quaternary formations, but the above will, we believe, give a fairly correct view of the general facts.

STRUCTURAL GEOLOGY.

The geologic structure of the Higginsville sheet is extremely simple. It is well displayed upon the map and section sheet accompanying this report, and only a few words are needed in addition to direct attention to what is there represented. The strata lie conformably upon each other, with the exception of the Warrensburg sandstone, which is uncomfortable upon the members of the Lower and Middle Coal Measures, as already explained. These strata are seen to have a slight northwesterly dip when widely separated exposures are compared, but within limited areas they appear to occupy practically horizontal positions. Thus, along the river bluff, about three miles west of Waverly, the Mulky coal bed is at an altitude of about 760 feet A. T.,* while about 10 miles further west, at the mouth of the Tabo creek, the altitude of this same bed is about 705 feet A. T. Along the Chicago & Alton railway, the altitude of the Mulky bed south of Corder is about 780 feet A. T., and some ten miles west, near Higginsville, the horizon of the coal referred to the Mulky bed is about 750 feet A. T.

In the southwestern corner of the sheet there is evidence of a dip to the northwest of the Mulky coal bed and of the immediately associated strata, while the Lexington coal bed remains horizontal. Consequently the interval between the two increases as is exhibited in the cross section N — O, on the section sheet.

A comparison of the various horizon lines with the contour lines on the map will reveal a number of minor undulations, producing local dips at different points; these are to be attributed both to irregularities of movement in the uplifting and depressing which this area was subjected to, as well as to unequal settling of the subjacent strata during the period of their deposition and to inequalities in original deposition.

ECONOMIC GEOLOGY.

The mineral of most economic importance in the Higginsville area is, at present, emphatically coal. Of minor importance are the clays, shales and building stones.

COAL.

Coal is mined on a large or small scale at a great number of points, most of which are designated on the map. The mining is prosecuted chiefly in one bed, which is known as the Lexington bed, from its early discovery and extensive later development in the vicinity of the town of Lexington, further west in the county. In addition to this, however, three other separate beds are recognized as operated within our area. These are, in descending order, first, the Mulky coal bed, named from its occurrence on Mulky creek, a few miles south of Aullville; next, the coal bed operated at Edwards station, on the Missouri river, and last, the Waverly coal bed, operated by shafts at that point. These beds we will now describe successively, beginning with the lowest.

THE WAVERLY COAL BED. By reference to the sections of the section sheet, and to sections I and II on previous pages, it will be seen that the Waverly coal bed is assigned a position about 130 feet below the top of the Lower Coal Measures. The existence of a coal bed at about this horizon has been suspected from the results of deep drilling in past years in this neighborhood, and its presence has been considered possible from the knowledge that there yet existed a great thickness of comparatively unexplored Coal Measure rocks beneath the coal beds worked in this neighborhood. Not

until the spring of 1891, however, was this conclusively demonstrated, when a trial shaft was put down at Waverly by the Middleton Coal Co. This shaft is located immediately north of the railway on the river bank; a section of it is given in section II. The total depth is about 75 feet. Two other coal seams, it will be noticed, were passed through before the lowest, or Waverly bed, was reached; these were, however, too thin to be of economic importance. The following section of the Waverly bed was measured here by Mr. Gluck:

SECTION XXXIII.

WAVERLY COAL BED AT MIDDLETON COAL CO.'S SHAFT.

		Feet.	Inches.
1	Shale, *soft, dark brown, growing darker toward the coal, with thin, lenticular layers of coal*	10	
2.	COAL		10½-12
3.	Shale, parting, *pyritiferous, not persistent*		¼-1½
4.	COAL		13-16
5.	Shale, parting, *persistent, non-pyritiferous*		1½-2½
6.	COAL		6
7.	Clay.		
	Total thickness of coal	1 ft. 8 in.	

Mr. Gluck reports that the coal contains pyrite in plates about one-sixteenth of an inch thick, which occurs along the joint planes. Little calcite or selenite was observed. The coal appeared hard and clean, breaking with a sharp fracture.

The Waverly Coal and Mining Co.'s shaft is about one-eighth of a mile east of the last, and is located on the map. The platform is about 10 feet above the railway, and the shaft is about 102 feet deep. Notes from the record of this shaft are given under section 1. Five thin streaks of coal are shown there to overlie the bed operated; none of them of economic value, however.

The following section of the Waverly bed was measured by the writer:

SECTION XXXIV.

WAVERLY COAL BED AT WAVERLY COAL & MINING CO.'S SHAFT.

		Feet.	Inches.
1.	Shale, *gray, sandy*	1	6
2.	Shale, *black, tenaceous*	1	6
3.	COAL	2	8
4.	Shale, parting		7½-2
5.	COAL		7-8
6.	Shale, *sandy, hard*.		
	Total coal	3 ft. 4 in.	

A sample of this coal was collected by the writer for analysis, chips being taken across the face of several large blocks of coal representing the whole face of the bed.

The following are the results of the analysis made by Mr. J. D. Robertson, in the Survey Laboratory:

ANALYSIS OF WAVERLY COAL, WAVERLY C. & M. CO.'S SHAFT.

(Analysis No. 271, Mo. Geol. Survey.)

Moisture	0.50	per cent.
Volatile hydro-carbon and sulphur	40.40	" "
Fixed carbon	44.46	" "
Ash and sulphur	14.55	" "
Total	100.00	" "
Sulphur of combustion (deleterious)	4.91	" "
Sulphur remaining in ash	.18	" "
Total sulphur	5.09	" "

LABORATORY NOTES. The coal ranks by composition as a highly bituminous coal. The specimens of the sample were of medium hardness, had a bright lustre, contained much selenite and calcite along the joint planes, but little pyrite. The sulphur contents is high, as is also the per centage of ash. The moisture is abnormally low. In a small porcelain crucible the powdered coal yields a firm porous cake with a sub-metallic, graphitic lustre. The ash is of a dark violet red color.

The results of the laboratory work show that this coal has an ample supply of hydro-carbon to permit its use for the manufacturing of gas, but whether this is of sufficient candle power can be determined only by a more elaborate "ultimate analysis." The high sulphur percentage does not, however recommend it for such use, and unless this can be reduced the, coal could not, at present, compete with other gas coals. The crucible test shows that this coal may possibly be a coking coal, but experimental work on a large scale is necessary to determine this. The high sulphur and ash contents would injure the sale of the coke in the market.

The Francisco shaft is located on the map, and is there seen to be on the west edge of the town of Waverly, adjacent to the railway. The shaft is 105 feet deep and the top is about at the level of the railway. The following section of the coal bed was here measured by the writer:

SECTION XXXV.

WAVERLY COAL BED AT FRANCISCO SHAFT.

		Feet.	Inches.
1.	Sandstone, *shaly, micaceous, soft*	2	6
2.	Shale, *black*	3	
3.	COAL, *shaly, pyritiferous*		6
4.	COAL, *good*	2	6
5.	Clay, parting		2
6.	COAL		8
7.	Shale and Coal		3
8.	Sandstone, *shaly, like 1*	5	
	Total thickness	3 ft. 8 in.	

These are all the openings which have thus far been made in the Waverly coal bed. At other points within the area, however, coal has been struck at depths by drilling, which probably belongs to this horizon. Thus, in the Catron well (Section XII, No. 7), a coal bed about three feet thick is reported to have been encountered at a depth of about 130 feet below the top of the Lower Coal Measures, which, if present, is doubtless the Waverly bed. Similarly in the deep well at Aullville (Section XV, No. 15, p. 33), the record shows the presence of a coal bed over two feet thick at a depth of about 150 feet below where we place the top line of the Lower Coal Measures, which coal we would also class as the Waverly bed. Finally, the lowest coal bed, five inches thick, struck in the drill-hole at Corder (Section XXVI, No. 52, p. 40), is at the proper horizon to be classed as the Waverly bed; whether the apparant thinness of the bed is an actual fact, or whether it is a result of the imperfections of the churn-drill, we are unable to say. At the Froeschly place, in section 8, township 49 N., 25 W., a drill-hole was put down to a depth of 240 feet or more, and the driller reports that a coal bed three to four feet thick was encountered, about 200 feet below the Lexington bed, or about 130 feet below the top of the Lower Coal Measures.

The suggestions conveyed by these results of drilling, together with the demonstration of the existence of this coal bed at Waverly, are sufficient to warrant further drilling and exploration in search of it over the contiguous country. The

results of drilling done between Waverly and Edwards station, which are withheld from publication, indicate both that this bed dips to the west from the former point, and that there is a thickening of the overlying rocks westward.

The horizon of this bed is so deep below the surface here that it extends under the whole area represented by the sheet, and the questions to be determined are its exact depth beneath the surface and its thickness and character at different points. The nature of the coal and of the associated strata as developed at Waverly, strongly suggest that the bed is the same as that mined so extensively in Randolph county, at Huntsville and elsewhere. We postpone decision concerning such correlation, however, until the intervening area is more thoroughly studied.

THE EDWARDS COAL BED.

The shaft of the Riverside Coal Company, at Edwards station, is described under Sec. IX. The coal operated here, which occurs at the base of this shaft, is about 15 inches thick, and is assigned a position about 100 feet below the top of the Lower Coal Measures. This is some 30 feet higher stratigraphically than is the Waverly bed at Waverly. This fact, together with considerations of the thickness of the coal and the association of the strata, combined with the inference from the results of the drilling between Edwards station and Waverly, above referred to, lead to the conclusion that the coal bed at Edwards station is not the Waverly bed, but that it belongs higher in the section and is, perhaps, as much as 100 feet above the latter at this point. This bed is below the level of the Missouri river over the whole area, and hence is not exposed nor does not crop out anywhere here. The following section of this coal was measured in the shaft by the writer:

SECTION XXXVI.

EDWARDS COAL IN RIVERSIDE SHAFT.

		Feet.	Inches.
1.	Limestone (?) *clayey, pyritiferous, fossiliferous*	1	8
2.	Shale, *black*	2	
3.	Shale, *calcareous, hard, black*		10

4.	Shale, *black, fissile*	2	
5.	Coal	1	3⅓
6	Clay	4	6
7.	Limestone (not seen)		
	Total coal	1 ft. 3⅓ in.	

A sample of this coal was collected by the writer, consisting of chips taken along a cross-section of a large lump of coal which had been freshly mined from the foot of the shaft. The results of the analysis of this sample made by Mr. J. D. Robertson in the Survey Laboratory are as follows:

ANALYSIS OF EDWARDS COAL, RIVERSIDE COAL CO. SHAFT.

(Analysis No. 213, Mo. Geol. Survey.)

Moisture	4.97	per cent.	
Volatile hydro-carbon and sulphur	42.06	"	"
Fixed carbon	42.27	"	"
Ash	10.70	"	"
Total	100.00	"	"
Sulphur of combustion (deleterious)	5.07	"	"
Sulphur remaining in ash	.59	"	"
Total sulphur	5.66	"	"

Laboratory Notes. This coal ranks as a highly bituminous coal, exhibiting much pure bitumen. No pyrite was observed, but considerable selenite occurs along the joint planes. It cokes well in a small porcelain crucible, the product being firm and hard, with a graphitic lustre. The ash is of dark, brick red color. The sulphur and moisture percentages are high, the ash moderate.

The highly bituminous character of the coal and the coking qualities exhibited would recommend it for gas uses were the sulphur contents not so high, and if the candle power of the gas is sufficient. The laboratory results indicate quite strongly that a good coke may be produced from this coal, but the high percentage of sulphur is here an objectionable factor.

The Edwards coal has not been identified at any other point within the area. It is probably of limited extent, at least that portion of it which is of workable thickness. It is possible that it may be represented by some one of the thin coal seams which were encountered in the shafts at Waverly, above the Waverly bed, or by the second coal bed from the bottom in the Corder drill-hole. The available date will not, however, authorize more than a suggestion in this direction.

THE MULKY COAL BED.

The Mulky coal bed is in the Middle Coal Measures, and occupies a place about twenty feet above the base of that formation. Its position is clearly shown on the map and in the various sections of the section sheet accompanying this report. Only at one point, strictly speaking within the area of the sheet, is the bed operated, namely, at the Corder shaft, south of Alma. Immediately beyond the southern line, however, this bed is worked at several points.

The Corder shaft is located on the map about three miles southeast of the town of Alma. It is only 18 feet deep. The following section was obtained by the writer from a miner at this shaft:

SECTION XXXVII.

MULKY COAL BED AT CORDER SHAFT.

(No. 10 of Section Sheet.)

		Feet.	Inches.
1.	Limestone	1	2
2.	Shale, *black, fissile*	5 to 6	
3.	COAL	1	6
4.	Clay	4	
	Total coal	1 ft. 6 in.	

This coal bed is clearly recognized only south of the Chicago and Alton railway, and here only at somewhat widely separated points. In section 12, township 49 N., 25 W., in the creek bed, near the middle of the west line, coal is exposed and was seen by Mr. C. F. Marbut. This we consider to belong to the Mulky bed. The overlying shale and limestone are to be seen in the creek banks and the following section of these was measured by the writer:

SECTION XXXVIII.

ROCKS OVER MULKY COAL, SEC. 12, TWP. 49 N., 25 W.

		Feet.	Inches.
1.	Limestone, *flaggy*	1+	
2.	Shale, *clayey, yellow*	1	
3.	Shale, *black, fissile*	3	

About two miles south of this, in section 24 of the same township, are several openings, located on the map, in coals which we assign to the Mulky bed. Norwood refers to such

in his manuscript, on the Roberts and Harrison farms, and he states that the coal bed is from 24 to 26 inches thick, and the overlying black strata 5 or 6 feet thick, from information furnished by Mr. Harrison. On a recent visit the following section was measured by the writer at the pit shown on the map near the middle of section 24:

SECTION XXXIX.

MULKY COAL BED, SEC. 24, TWP. 49 N., 25 W.

		Feet.	Inches.
1.	Limestone	1	3
2.	Shale, *clayey, yellow*	1	
3.	Shale, *black, fissile*	6	
4.	COAL	1	6
	Total coal	1 ft. 6 in.	

The coal encountered in the well, half mile west of the last point, belongs, undoubtedly, to the same bed. The coal in the Stapp well, shown on the map, in section 14 of the same township, and the coal formerly mined in the creek bed a quarter of a mile west, are assigned to the same horizon.

The Payne drift is on the south line of section 15, in the southeast quarter. It enters the hill-side just above the county road. The mine was abandoned at the time of inspection, and no measurements of the bed could be made. Broadhead gives the following section of a coal bed and associated rocks on Charles Payne's land, two and one-half miles east of Aullville, which is presumably the same:

SECTION XL.

MULKY COAL BED, CHARLES PAYNE'S LAND. *(From Broadhead.)**

		Feet.	Inches.
1.	Limestone.	4	
2.	Slate.	2	
3.	Shale, *pyritiferous and bituminous with many fossils, mostly Chonetes mesoloba*	1	6
4.	Clay, *black*		4
5.	COAL, *bituminous*	1	6
6.	Fireclay.		
	Total coal	1 ft. 6 in.	

The following results of analysis of this coal are also included in the same report:

* Report Mo. Geological Survey, 1872, Part II, p. 47.

	TOP.	MIDDLE.	BOTTOM.
Water	8.85	7.02	7.75
Volatile	37.27	37.67	34.05
Fixed carbon	44.80	39.66	40.03
Ash	9.10	15.65	18.17
Color of each	Cream.	Very light brown.	Lt. chocolate.

These results show the coal to be decidedly bituminous, but with a somewhat high percentage of ash. Broadhead classes this coal as of the Lexington bed. We differ from him in this determination and assign it to the lower Mulky coal bed. The topographic position is in support of this view; the nature of the section, especially the great thickness of the overlying shale is further reason for this conclusion, and finally, a bed which we unhesitatingly recognize as the Lexington bed is dug north of this in the uplands 40 or 50 feet above the level of the coal at Payne's. At Aullville, in the drill-hole described under section XV, on page 33, a coal bed struck about 30 feet beneath the surface is thought to possibly represent the Mulky bed. If this be the case, it acquires a noticeable westwardly dip at this point, the bed being here some 60 feet below its level at the Payne drift. A mile or more west of this again, in the Roberts and Parker drill-hole, the coal bed numbered 12, in section XXX of p. 44, is also assigned to the Mulky bed. This bed is still 20 feet lower than that at Aullville, and this adds further support to the hypothesis of a westerly dip of the Mulky coal bed here.

In the drill-hole at Corder no coal is reported to have been encountered at the position where we might expect to find the Mulky bed, namely about stratum 21 of section XXVI, on p. 41. The presence of the limestone beds here with the body of shale between, suggest that the coal does not extend this far, while the associated strata do. North and east of this, in the Catron well, in section 4, township 50 N., 24 W., the coal of the stratum numbered 5, of section XII, is considered to be the Mulky bed, as is also that dug in the hills along Salt creek, at the Smith pits, about a mile west of Catron's. The coal at Smith's could not be seen when the locality was visited, but the owner of the land states that the bed is about a foot thick, and overlain by black shale. Again, south of Dover,

along a fork of Tabo creek, the Mulky bed makes its appearance as is indicated on the map. The Luke drift at this locality is in the Mulky bed. This drift has been abandoned for a number of years and no measurements could be made here. In the Phillips well, referred to on p. 38, the lowest bed encountered is assigned to the Mulky bed; it is reported to be about 22 inches thick. Finally, at the mouth of Tabo creek, the coal numbered 3 in section XVIII, is considered to belong to the Mulky bed.

As already stated, the presence of the Mulky bed is best established and its area is best defined in the south-eastern portion of our sheet, and here the horizon line of the bed is shown on the map. In the northern portion of the area the presence of the bed over any considerable portion seems doubtful, or at least its presence in workable thickness can hardly be considered established. Hence it is deemed advisable to omit the delineation of the horizon over this area, though it occurs well above the drainage level.

THE LEXINGTON COAL BED.

As has been already stated in this report, the normal position of the Lexington coal bed here is about 70 feet above the bottom of the Middle Coal Measures. Its place and distribution are clearly displayed on the map and accompanying sections. It is the most extensively operated bed within the area, and has, at present, greater economic prominence than any one of the beds thus far described. This is due largely to its topographic position, and, as a result, its extent is much better defined. The mines north of Dover are operating this bed, as are also those in the vicinity of Corder, those about Higginsville and those west of Aullville. Beginning with the openings along the Missouri river, north of Dover, we will now describe successively each one concerning which information could be obtained.

The eastmost point along the river at which we have any reliable notice of the existence of the Lexington coal bed is in section 12, of township 51 N., 25 W. No mines have been

operated here during recent years, but at the time of Mr. Edwin Harrison's examination of this county, several seem to have been in operation. Of these he gives the following description:

SECTION XLI.

LEXINGTON COAL BED, GEO. FLETCHER MINES, S. E. ¼—S. W. ¼—SEC. 12, 51 N., 25 W.

(From Edwin Harrison.)

		Feet.	Inches.
1.	Limestone, *hard, bluish and buff, heavy bedded, compact*	2	6
2.	Limestone, *bluish and yellowish, in layers from 6 to 18 inches thick; separated by seams of yellow shale, from 1 to 4 inches thick*	3	6
3.	Shale, *light yellow, argillo-calcareous*	1	9
4.	Limestone, *bluish, weathering yellow to the depth of several inches; hard, compact, uneven bedded*	4	
5.	Clay, *yellow*		1
6.	Shale, *black, argillo-bituminous*		3
7.	COAL, *good*	1	
8.	Slope to river level	85	
	Total coal	1 ft.	

Concerning the coal at this locality, Mr. Harrison adds the following: "The mines suddenly narrow vertically and occasionally; though (as I am told by Mr. Sullivan) the bed is generally about 2 feet thick, it not unfrequently narrows down to 2 or 3 inches, or even gives out entirely."

In the adjoining section to the west, about a mile and a half from Fletchers, the following section occurs:

SECTION XLII.

LEXINGTON COAL BED, SULLIVAN MINES, W. ½—S. W. ¼, SEC. 11, 51 N., 25 W.

(From Edwin Harrison.)

		Feet.	Inches.
1.	Limestone, *interstratified with yellow argillaceous shale*	1	9
2.	Shale, *yellow, argillo-calcareous*		9
3.	Limestone, *bluish, weathering yellow, uneven bedded*	4	6
4.	Shale, *reddish, yellow and argillo-calcareous*		1
5.	Shale, *lead colored, argillaceous*		3
6.	Shale, *bluish black, argillaceous*		3
7.	Clay, *yellow and blue*		3
8.	COAL	1	
	Total coal	1 ft.	

About two miles west of this, in the river bluff near the west line of section 9, of the same township, is the Spruel drift. This is located on the map. Here the following section was measured by Mr. Leo Gluck:

SECTION XLIII.

LEXINGTON COAL BED, SPRUEL DRIFT.

		Feet.	Inches.
1.	Limestone, *blue*	2	
2.	Intervel (limestone and shale)	8	
3.	Limestone, *blue, compact*	3	6
4.	Shale, *soft, black*		5
5.	COAL	1	3
6.	Interval to railway level	75	
	Total coal....1 ft. 3 in.		

About a mile southwest of this, near the middle of the N. W. ¼ of section 17, Harrison describes the following section high up in the bluffs, at the Parker mines:

SECTION XLIV.

LEXINGTON COAL BED, PARKER MINES.

(From Edwin Harrison.)

		Feet.	Inches.
1.	Limestone	3	3
2.	COAL		4
3.	Clay, *dark, blue, argillaceous*		$1\frac{1}{2}$
4.	COAL, *good*	1	8
5.	Shale or clay, *blue and yellow, argillaceous*	1	
6.	Slope....100 (? A. W.)		
	Total coal ....2 ft. 0 in.		

About a quarter of a mile southwest of this, in the same section, is the Steele and Davis or the Dover Coal Co.'s drift, which is located on the map, in side of the bluff immediately above the railway. Here the following section was measured by Mr. Leo Gluck:

SECTION XLV. (See plat on Section Sheet.)

LEXINGTON COAL BED, STEELE & DAVIS DRIFT.

		Feet.	Inches.
1.	Limestone	4	
2.	Shale, *fissile, black, not persistent*		$2\frac{1}{2}$
3	COAL ("top coal")		$6\frac{1}{2}$
4.	Clay band		3
5.	COAL	1	$5\frac{1}{2}$
6.	Clay, dark ("mining")		3
7.	Fire-clay	2—4	
8.	Limestone.		
	Total coal....2 ft. 0 in.		

Pyrite was observed by Mr. Gluck at the mine throughout the coal in flakes and also in nodules. The underclay attains a thickness of 5 feet in places. The "Top Coal" was observed

to be not persistent and is absent about half the time. Rolls or faults also diminish the thickness of the coal in places. The thinness of the shale or "slate" over the coal is a disadvantage here, inasmuch as it does not supply enough "packing," and, hence, the soft bottom clay has to be used, which is an inferior material. The coal is shipped to neighboring points on the railway and to Kansas City and to Nebraska for domestic and steaming purposes.

Samples of the coal from the two benches were collected by taking chips from several faces in the mine. The following are the results of this analysis of these samples made by Mr. J. D. Robertson in the Survey laboratory:

ANALYSES OF LEXINGTON COAL, STEELE & DAVIS DRAFT.

(Top bench, Analysis No. 218, Mo. Geol. Survey.)

(Bottom bench, Analysis No. 228, Mo. Geol. Survey.)

	TOP BENCH.		BOTTOM BENCH.	
Moisture	6.44	per cent.	4.96	per cent.
Volatile hydro-carbon and sulphur	39.61	" "	40.79	" "
Fixed carbon	44.79	" "	42.74	" "
Ash	9.16	" "	11.51	" "
Total	100.00	" "	100.00	" "
Sulphur of combustion (deleterious)	4.07	" "	4.24	" "
Sulphur remaining in ash	0.18	" "	0.04	" "
Total sulphur	4.25	" "	4.28	" "

LABORATORY NOTES. Both of these coals are to be classed as bituminous, that of the bottom bench being more so than the upper. The latter appears as a hard bright coal with some shale interlaminated, but with little pyrite or selenite: the ash is of brick red color. The coal of the lower bench is of duller lustre, carries more shale, and a considerable amount of visible pyrite, but little selenite; the ash is of a salmon red color. Neither of these coals coked in the crucible. The moisture and sulphur percentages are high, the ash percentages moderate.

The high percentage of volatile hydro-carbon commends this coal for use in gas manufacture, if the candle power is adequate. The high sulphur percentage is, however, an obstacle to such use. The fact that the coal did not coke in the crucible is against its being used for the manufacture of coke and also affects its value as a gas coal.

The Tubman mine, about two miles southeast of the last in the N. W. ¼ of the S. W. ¼ of section 21, were apparently in operation at the time of Mr. Harrison's examination, and he

states in his manuscript, that the coal was consumed at the steam grist and saw mill at Dover. He gives the following section obtained here:

SECTION XLVI.

LEXINGTON COAL BED, TUBMAN'S MINES.

		Feet.	Inches.
1.	Limestone, *blue, uneven bedded*	2	
2.	Clay, *dark yellow*		3
3.	COAL		6
4.	Clay, *blue*		2
5.	Clay, *black, bituminous*		1
6.	COAL, *good*	1	7
7.	Fireclay, *blue*	1	
	Total coal	2 ft.	1 in.

Immediately north of this, in the same section, is a coal pit and outcrop on the Zeysing land, shown on the map. The pit was abandoned at the time of inspection, but the limestone was seen by Mr. Marbut, directly overlying the coal, with no intervening shale, and the coal was reported to him to vary from 18 to 32 inches in thickness. The Fox shaft, a little north of this, was also abandoned, but it was credibly reported to be about 40 feet deep; the coal is stated to be from 18 to 26 inches thick, and to be directly overlain by limestone, with no intervening shale. About two miles east of this, in section 23, an outcrop of coal is shown on the map, in the bed of a branch. It was located by Mr. Marbut and is seen to be overlain directly by 3½ feet of limestone.

The Van Anglen drift, a mile further east, at the middle of the west line of section 24, was also visited by Mr. Marbut. The coal here was about 17 inches thick and is directly overlain by about three feet of limestone.

Beyond this to the east, no further occurrences of the Lexington coal bed are known.

Along the Chicago & Alton railway, and in the country immediately north of this road, the Lexington coal bed is mined at several points. The eastmost occurrences of which we have notice, are at the Lewis drifts, in section 18, of township 59 N., 24 W., which are shown on the map. These drifts were abandoned at the time of inspection, and the thickness

of the coal could not be measured. The limestone cap rock was, however, exposed to a thickness of three or four feet. Other sections closely associated with the coal bed here are described elsewhere in this report.

The Price well (churn-drill hole), is about a mile and a half southwest of the Lewis drifts, near the south line of section 24, in township 50 N., 25 W. Here coal, reported to be 18 inches thick, was struck at a depth of 30 feet, which is undoubtedly the Lexington bed.

The Smith shaft is less than half a mile west of the Price well. This was also abandoned at the time of visit, but the following record was obtained from a miner who had sunk the shaft:

SECTION XLVII.

LEXINGTON COAL BED, SMITH SHAFT.

		Feet.	Inches.
1.	Shale	5	
2.	Clay, *hard*	3	
3.	Limestone	2	
4.	Shale, *black, fissile*		1
5.	COAL, soft	1	6
4.	Limestone	3	
	Total coal	1 ft. 6. in.	

The Corder Coal and Coke Co.'s shaft is on the western edge of the town of Corder. A record of the shaft and deep drill-hole are given on p. 40 of this report. The shaft is about 100 feet deep. The following detailed section of the coal bed was measured here by Mr. Gluck:

SECTION XLVIII.

LEXINGTON COAL BED, CORDER COAL & COKE CO. SHAFT.

		Feet.	Inches.
1.	Limestone	20	
2.	Shale, *black* ("*top slate*")		4
3.	Shale, *black* ("*black slate*")		8
4.	Shale, *black* ("*band slate*"), *lower half generally quite soft and pyritiferous, and with concretions*		4½
5.	COAL ("*top coal*"), *with selenite crystals and pyrite*	1	4
6.	Clay, parting		½
7.	COAL ("*bottom coal*")		3½
8.	Fire-clay		8
	Total coal	1 ft. 7½ in.	

"Rolls" and "horsebacks" occur in the bed here. The coal is not so clean as some of the Higginsville coals, and its value is, hence, somewhat impared. It cokes in burning, but a rough attempt at coking the coal did not yield satisfactory results. The product of the mines is shipped to Kansas City and to neighboring points, for domestic and steam purposes.

Two samples of coal were collected here by Mr. Leo Gluck, one from the top bench, and the other from the lower bench. Each was made up of a series of chips taken from across the face in different parts of the mine. The following are the results of the analyses made by Mr. J. D. Robertson in the Survey laboratory:

ANALYSES OF LEXINGTON COAL, CORDER COAL & COKE CO.'S SHAFT.

(Top bench, Anal. No. 226, Mo. Geol. Survey.)

(Bottom bench, Anal. No. 229, Mo. Geol. Survey.)

	TOP BENCH.	BOTTOM BENCH.
Moisture	5.67 per cent.	7.03 per cent.
Volatile hydro-carbon and sulphur	37.67 " "	37.44 " "
Fixed carbon	44.02 " "	45.73 " "
Ash and sulphur	12.64 " "	9.80 " "
Total	100.00 " "	100.00 " "
Sulphur of combustion (deleterious)	5.31 " "	3.97 " "
Sulphur in ash	.25 " "	.10 " "
Total sulphur	5.56 " "	4.07 " "

LABORATORY NOTES. The coal from the top bench has a dull lustre, contains much pyrite but little shale or selenite; the ash is of lilac drab color. The coal of the bottom bench has a brighter lustre, is hard and brittle, has much selenite, little pyrite but considerable melanterite; the ash is of a dark red color. Neither of these coals coked in the porcelain crucible.

The moisture in both coals is to be considered high, and the ash and sulphur also. The coal ranks as a bituminous coal, but is not so rich in volatile matter as the preceding coals of which the composition is given. The percentages are, however, ample for the coal to be used for the manufacture of illuminating gas, if the candle power is sufficiently high and were the sulphur contents lower. The results reached in the laboratory are adverse to the coals' being coking coals.

Immediately north of the town of Corder, in the Grove well, the Lexington coal bed was encountered about 18 inches thick at a depth of 60 feet. *The Fields* and the *McCarty shafts* are

within a mile of this to the west. The Lexington coal bed was operated in each, at a depth of 20 and 28 feet respectively. The thickness of the coal is about the same as in the Corder shaft.

James Carter's mine is described in Mr. Harrison's notes as being in the S. W. ¼ of the N. W. ¼ of section 22, township 50 N., 25 W., and thus immediately north of the McCarty shaft. Here he measured and describes the following section:

SECTION XLIX.

LEXINGTON COAL BED, JAS. CARTER MINE.

		Feet.	Inches.
1.	Limestone, isolated blocks.		
2.	Slate *bituminous, with small lenticular concretions*		6
3.	Clay, *yellow*		2
3.	Slate, *bituminous, small lenticular concretions*		9
4.	COAL, *good, bituminous*	1	6
5.	Clay, *dark, blue*		½
6.	COAL, *containing pyrite*		2
7.	Clay, *dark blue*		6
	Total coal	1 ft.	8 in.

Schoppenkoetter's drift is less than a mile north of the last point. It has been abandoned for some time and no measurements could be made. Harrison, however, gives a section at an old mine (J. G. Webb's) closely adjoining, in N. W. quarter of the S. W. quarter of section 15, as follows:

SECTION L.

LIMESTONE AT J. G. WEBB'S MINE.

		Feet.	Inches
1.	Limestone, *blue, inclined to purplish, coarse grained, crystalline, homogeneous, even fracture, compact. Composed of comminuted remains of Crinoids*	1	
2.	Limestone, *blue, fine grained, smooth fracture, uneven bedded. Fusulina cyl., Athyris subtilita and a Crinoid*	4	

At Neer's well, in the southeast quarter of section 5, coal is reported to have been struck at a depth of 30 feet which we consider to be the Lexington bed.

The Ritter shaft, on the east line of section 17, was abandoned at the time of inspection and no measurements could be made. The Grove drift, about a mile west in section 18, is in a similar condition. A limestone outcrop about three feet thick was observed here, however.

At the Neale well, half a mile south of the last, in section 19, the following record was furnished by the driller:

SECTION LI.

LEXINGTON COAL BED, NEALE WELL.

		Feet.	Inches.
1.	Limestone (cap rock)	9	
2.	Shale, *black fissile*	1-2 (?)	
3.	COAL	1	6
4.	Fireclay.		
5.	Limestone.		
	Total coal	1 ft. 6 in.	

Mr. Neale reports that the coal here is 22 inches thick and was encountered at a depth of 32 feet; a second coal 12 inches thick was struck at a depth of 170 feet. The drillers estimate the depth of the last coal at about 150 feet.

South of the Chicago & Alton railway and east of Higginsville, the Lexington bed is dug on a small scale at a number of points, chiefly for local country sale. The openings are principally near the heads of small streams which drain southward into Davis creek.

The Boyle drift and well near the middle of section 7, of township 49 N., 24 W., is about the eastmost occurrence of the Lexington coal in this district. The drift is abandoned, but Mr. Marbut measured the coal bed here and found it to be from 16 to 20 ins. thick, to be overlain by about two feet of shale and underlain by clay. In the well closely adjoining, the coal was struck at a depth of 22 feet and limestone and sandstone (?) are both reported to have been encountered over the shale. At the Shumaker well, half a mile north of the last, 18 to 20 inches of coal, overlain by 30 inches of shale, were encountered.

Summer's drift is half a mile northwest of the last, in the southwestern corner of section 1. The works are all caved in here and no measurements could be made.

The coal is credibly reported by a resident to be between 22 to 26 inches thick, and to be overlain by from 2 to 2½ feet of black fissile shale, which in turn is overlain by about 12 feet of limestone. Between the shale and the coal is a few inches

of soft pyritiferous clay or shale. Adjoining this are several other coal pits, none of which have, however, been recently operated, and are now filled in so that no measurements could be made.

At the Water's well, a mile north of the last, in the southwestern corner of section 21, township 50 N., 24 W., the Lexington coal bed was struck at a depth of about 40 feet.

The Edward's shaft is a mile west of the Water's well, in the southwestern corner of section 36, township 50 N., 25 W. Here the thickness of the coal is reported to be about 2 feet, but it could not be measured at the time of inspection, as the shaft was abandoned. In a well on the same place, closely adjoining the shaft, the overlying limestone is reported to be as much as 22 feet thick. This is an abnormal thickness, but it agrees well with that reported in the Corder shaft about two miles northwest.

The Bell drift is about a mile west of the Edwards shaft, in the northwestern corner of section 2, township 49 N., 25 W. Here the following section was recently measured by the writer:

SECTION LII.

LEXINGTON COAL BED, BELL DRIFT.

		Feet.	Inches.
1	Limestone (*partially exposed*)	2	
2.	Shale, *black, fissile*	1	8
3.	Shale, *soft, black*		3
4.	COAL	1	8
	Total coal	1 ft. 8 in.	

The altitude of the coal at this point is 820 feet, while at the Edwards shaft, it will be seen by a study of the map, the coal is at an altitude of about 790 feet, A. T. This shows a decided dip of the coal towards the east.

About half a mile down the stream which heads near the Bell drift is the Frank Corder drift. Here, limestone, 6 to 8 feet thick, is exposed, underlain by 18 or 24 inches of black shale, between the limestone and the coal. The nature of the section here leaves no doubt but that this coal is of the Lexington bed. Its elevation at this point is about 780 feet, A. T.; hence the fall of the coal from the Bell to the Corder shaft is about 40 feet in a distance of not much over half a mile. This

easterly dip does not extend far, however, for about two miles farther east, at the Boyle place, the coal is again at an altitude of about 800 feet. From this we recognize the existence of a slight synclina flexure here, the axis of which runs southwestwards through the Edwards shaft. To this flexing the dip of the Mulky coal at Aullville, already referred to, may be attributed in part.

The Van Meter pit is a small stripping along the bed of a branch, near the northwestern corner of section 10, township 49 N., 25 W. The following section was recently remeasured here by the writer:

SECTION LIII.

LEXINGTON COAL BED, VAN METER PIT.

		Feet.	Inches.
1.	Limestone *(partially exposed)*	2	
2.	Shale, *black fissile*	2	
3.	Coal	1	10
	Total coal	1 ft. 10 in.	

The altitude of the coal here is about 780 feet A. T., or the same as at the Corder drift last described. At the Frazier drifts, about a mile southwest of the Van Meter, all is fallen in and no measurements were made.

Petty's drifts are located in the southwestern corner of section 33, township 50 N., 25 W. Several openings have been made in the coal here by drifts and shafts. The coal is about 20 inches thick and is overlain by about a foot of black shale. The altitude of the bed is about 820 feet A. T., or about the same as that of the Bell drift.

The Schaffer drift is about a mile and a half east of Petty's, at the middle of the north line of section 5, township 49 N., 25 W. Here the following section was measured by Mr. Gluck:

SECTION LIV.

LEXINGTON COAT BED, SHAFFER DRIFT.

		Feet.	Inches.
1	Shale, *black, fissile*	2	1
2.	Coal		16 to 22
3.	Clay		4-6
	Total coal	16 to 22 in.	

The Wagner drift, less than half a mile south of the Schaffer, is abandoned. About five feet of the cap rock is ex-

posed here, and the underlying shale is about 2 feet thick. Several other drifts have been operated in this immediate neighborhood, but they are all abandoned now.

The Froeschley shaft, in section 8, of township 49 N., 25 W., is about 20 feet deep. In it the following section was measured by Mr. Gluck:

SECTION LV.

LEXINGTON COAL BED, FROESCHLEY SHAFT.

		Feet.	Inches.
1.	Limestone ("Headrock")	6	6
2.	Shale, *black, fissile* ("Top slate")		1
3.	Shale, *black, fissile* ("Black slate")		11
4.	Shale, *pyritiferous*		3
5.	Coal		17 to 25
6.	Clay	2	
7.	Bottom rock.		
	Total coal	...17 to 25 in.	

The Graham drifts are about one mile west of Aullville, near the hill top, in section 20, of township 49 N., 25 W. They were abandoned at the time of inspection. The following measurements were made, however, by Mr. Gluck at the mouth of one of the drifts:

SECTION LVI.

LEXINGTON COAL BED, GRAHAM DRIFT.

		Feet.	Inches.
1.	Limestone, *broken and weathered, total thickness reported 7 feet, only exposed in part*	2	
2.	Clay		4
3.	Shale, *black, fissile* (reported to reach 32 inches)	1	9
4.	Coal (reported to be 19 inches thick)		17
5.	Clay.		
	Total coal	1 ft. 5 in.	

West of Higginsville, along the Chicago and Alton railway, and south of this along Rocky branch, the Lexington bed is more extensively mined than in any other portion of the area.

The Excelsior Coal and Coke Company's shaft is about half a mile west of the town, on the main line of the railway. The shaft is 70 feet deep. The following section of the bed was measured by Mr. Gluck; it represents about an average of several other measurements made in the same mine:

SECTION LVII. (See plat on Section Sheet.)

LEXINGTON COAL BED, EXCELSIOR COAL & COKE COMPANY.

		Feet.	Inches.
1.	Limestone.		
2.	Shale, *black, fissille* ("Top slate")		8
3.	Shale, *black, fissile* ("Black slate") *hard, with selenite and concretions.*	1	1

4.	Shale, *black, fissile* ("Band slate"), *adheres to coal, pyritiferous*			3
5.	COAL	Top bench		5
6.	Shale, parting *(not always present)*			$\frac{1}{8}$-$\frac{3}{8}$
7.	COAL			$8\frac{1}{2}$
8.	Clay band, *parting (regular)*			$\frac{1}{2}$
9.	COAL *(Bottom bench)*			$2\frac{3}{4}$
10.	Clay		1	
	Total coal			1 ft. $4\frac{1}{4}$ in.

The coal from this mine is shipped by rail to Kansas City and other points. It is mainly used for domestic purposes, but also for steaming. A rough test of the coking properties of the coal was made at the mine, but the product was weak and impure and was high in sulphur. The coal contains pyrite and selenite in thin laminae; it also clinkers in burning and slacks on exposure to the weather.

Two samples of this coal were collected by Mr. Gluck, made up from chips from the entire section of the benches, at five different points in the mine. The following are the results of the analyses of these samples, made by Mr. J. D. Robertson in the Survey laboratory :

ANALYLSES OF LEXINGTON COAL, EXCELSIOR COAL & COKE CO.

(Top bench, Anal. No. 221, Mo. Geol. Survey.)

(Bottom bench, Anal. No. 217, Mo. Geol. Survey.)

	TOP BENCH.	BOTTOM BENCH.
Moisture	7.69 per cent.	5.82 per cent.
Volatile hydro-carbon and sulphur	38.67 " "	38.83 " "
Fixed carbon	43.65 " "	45.66 " "
Ash	9.99 " "	9.69 " "
Total	100.00 " "	100.00 " "
Sulphur of combustion (deleterious)	2.62 " "	3.65 " "
Sulphur in ash	0.09 " "	0.05 " "
Total Sulphur	2.71 " "	3.70 " "

LABORATORY NOTES. The specimens of coal from the top bench are quite hard, with a somewhat dull lustre; they contain little shale or pyrite, but some selenite in thin plates; the ash is of a very light brick red color. The specimens from the bottom bench have a brighter lustre and a concholdal fracture; they contain pyrite, shale and selenite in small quantities; the ash is of a light brick red color. Neither coal coked in the small porcelain crucible.

These results show this coal to be high in moisture and ash, but moderate in sulphur contents for coals of this characer from this region. The coal, like the others already cited, is

distinctly a bituminous coal, with a sufficiently high percentage of volatile matter to class it as a gas coal, if the illuminating power is sufficient, and were the sulphur contents lower. In the present instance the sulphur percentage given is, however, as low as that of coals from Kansas which are used in Kansas City for the manufacture of gas. The results reached in the laboratory as well those from the tests made at the mine are adverse to the coal's being valuable for coking purposes, even were the sulphur percentage lower.

The Hawkins and Smith shaft is about a quarter of a mile northwest of the Excelsior shaft. It is 80 feet deep to the coal. The section of the shaft is given under No. XXXI on p. 44 of the report. The coal is 18 inches thick.

The Winsor Coal Company's shaft is half a mile west of the Hawkins and Smith shaft, on the railway, in section 2. The following section was measured here by Mr. Gluck, and is a fair average of five measurements made in different parts of the mine:

SECTION LVIII. (See plat on Section Sheet.)

LEXINGTON COAL BED, WINDSOR COAL COMPANY.

		Feet.	Inches.
1.	Limestone		
2.	Shale, *black, fissile* ("Top slate")		9
3.	Shale, *black, fissile*, ("Black slate")		9
4.	Shale, *black, fissile* ("Band slate"), *pyritiferous*		4
5.	Coal ("Top bench")	1	1
6.	Clay, *parting and pyrite*		3/8-1/2
7	Coal		3 1/2-4
8	Clay, *hard, black*		3-4
9.	Clay	2	6
	Total coal		1 ft. 5 in.

Mr. Gluck notes that both the top and bottom benches contain scales of selenite. The coal is reported not to slack readily and to cake and clinker in burning.

Concretions occur in the roof shale, and "rolls" in the floor and roof are frequent. The coal is shipped principally to Kansas City for domestic use, very little being used for steam purposes. A small lot of the coal is reported to have been used in the town of Marshall for the production of illuminating gas. Two samples of coal were collected here, one from each bench, consisting of chips cut from five different

faces in the mine. The following are the results of the analyses made by Mr. J. D. Robertson of the Survey laboratory:

ANALYSES OF LEXINGTON COAL, WINSOR COAL COMPANY.

(Top bench Anal. No. 209, Mo. Geol. Survey.)

(Bottom bench, Anal. No. 220, Mo. Geol. Survey.)

	TOP BENCH.	BOTTOM BENCH.
Moisture	7.52 per cent.	8.95 per cent.
Volatile hydro-carbon and sulphur	38.43 " "	34.38 " "
Fixed carbon	43 27 " "	41.93 " "
Ash	10.78 " "	14.74 " "
Total	100.00 " "	100.00 " "
Sulphur of combustion (deleterious)	3.01 " "	4.70 " "
Sulphur in ash	32 " "	.38 " "
Total sulphur	3.33 " "	5.08 " "

LABORATORY NOTES. The specimens of coal of the top bench have a bright bituminous lustre on fresh fracture, they contain some shale and a good deal of selenite and calcite, little pyrite, but much melanterite. The ash is of a medium, chocolate brown color. No coke was formed in the small porcelain crucible. The coal of the bottom bench has a duller lustre than that of the upper, but is otherwise similar.

These analyses show the coals to be high in moisture and ash. The coal is decidedly a bituminous one. The remarks made concerning the coal of the Excelsior shaft, on p. 81, with reference to the coking qualities of the coal and its use for gas manufacture, will apply here.

Along Rocky branch, immediately south of the last described shaft, are a number of shallow shafts and drifts, from which a large amount of coal has been mined and shipped. These are shown on the map. The following description of two of these will convey a fair idea of the character of the coal in all.

The Stealey and Fowler shaft No. 1 is in the S. W. ¼ of the N. E. ¼ of section 11, township 49 N., 26 W. The shaft is only 14 feet deep. The following section was measured here by Mr. Gluck and is a fair average of five measurements at different portions of the face:

SECTION LIX. (See plat on Section Sheet.)

LEXINGTON COAL BED, STEALEY & FOWLER SHAFT NO. 1.

		Feet.	Inches.
1.	Limestone.		
2.	Shale, *black, fissile ("Top slate")*		6 to 8
3.	Shale, *black fissile ("Black slate"), with concretions.*	1	
4.	Shale, *black fissile, ("Band slate"), pyritiferous.*		2½ to 3
5.	Coal ("Top bench")		10¾
6	Clay band, *soft*		½
7.	Coal ("*Bottom bench*")		4
8.	Clay, *dark*		3
9.	Limestone.		
	Total coal	1 ft.	2½ in.

Very little pyrite was noticed in the coal, but films of calcite or selenite are abundant in both benches. The coal has generally a very clean appearance. It is shipped chiefly to Kansas City for domestic uses and is reported to command a superior price to the others from the county. The operators also claim it to be suitable for gas production, it having been used in the town of Marshall for this purpose.

A sample of coal was collected by Mr. Gluck from each bench in this mine, by chipping fragments across the face at five different points in the workings. The following are the results of the analyses made by Mr. J. D. Robertson:

ANALYSES OF LEXINGTON COAL, STEALEY & FOWLER SHAFT NO. 1.

(Top bench, Anal. No. 226, Mo. Geol. Survey.)
(Bottom bench, Anal. No. 224, Mo. Geol. Survey.)

	TOP BENCH.	BOTTOM BENCH.
Moisture	6 23 per cent.	5 30 per cent.
Volatile hydro-carbon and sulphur	39.53 " "	39.48 " "
Fixed carbon	43.16 " "	44.96 " "
Ash	11.08 " "	10.26 " "
Total	100.00 " "	100.00 " "
Sulphur of combustion (deleterious)	3.64 " "	4.62 " "
Sulphur in ash	0.26 " "	0.08 " "
Total sulphur	3.90 " "	4.70 " "

LABORATORY NOTES. The specimens from both benches have a bright bituminous lustre, contain much selenite and considerable pyrite along the joint planes. Much bitumen was observable. The ash from the top bench is of a reddish salmon color; that of lower bench of a brick red color. Neither coal coked in the porcelain crucible.

The coal is to be classed as a bituminous coal like the others. The ash and moisture percentages are high, the sulphur moderate. The results reached in the crucible tests are adverse to the coking of the coal. The amount of sulphur present in the top bench, as was observed on p. 81, when speaking of the Excelsior Company's coal, is not greater than that in the other coals which are used in the State for the production of illuminating gas. If the candle power of the volatile hydrocarbons is sufficiently high the coal may, therefore, find a use in this direction.

The Belt drift No. 1, is about a quarter of a mile southwest of the Stealey and Fowler shaft, on Rocky branch. The following section was measured here by Mr. Gluck:

SECTION LX. (See plat on Section Sheet.)

LEXINGTON COAL BED. BELT DRIFT NO. 1.

		Feet.	Inches.
1.	Limestone.		
2.	Shale, *black, fissile* (" *Top slate* ")		8
3.	Shale, *black, fissile* (" *Black slate* "), *with concretions and pyrite*	1	
4.	Shale, *black, fissile* (" *Band slate* "), *pyritiferous*		2
5.	COAL (" *Top bench* ")	1	
6.	Clay, parting		3/4
7.	COAL (" *Bottom bench* ")		4
8.	Clay, *dark* (" *mining* ")		2 to 3
9.	Clay	3-4	
	Total coal	1 ft. 4 in.	

This coal has not so clean an appearance as that at the Stealey and Fowler shaft. It is mostly used for domestic purposes, being shipped to Kansas City, where it commands the same price as the coal last described. It cakes and clinkers in burning, and acts generally like the other coals mined about Higginsville.

A sample was collected by Mr. Gluck from each of the benches here, chips being taken across the face of five different faces. The results of analysis of these samples made in the laboratory of the Survey are as follows:

ANALYSES OF LEXINGTON COAL, BELT DRIFT NO. 1.

(Top Bench, Anal. No. 211, Mo. Geol. Survey.)

(Bottom bench, Anal. No. 231, Mo. Geol. Survey.)

	TOP BENCH.		BOTTOM BENCH.	
Moisture	5.84	per cent.	7 19	per cent.
Volatile hydro-carbon and sulphur	40.38	"	36.32	"
Fixed carbon	42.86	"	43.16	"
Ash	10.92	"	13.33	"
Total	100.00	"	100.00	"
Sulphur of combustion (deleterious)	3.17	"	3.08	"
Sulphur in ash	.51	"	.55	"
Total Sulphur	3.68	"	3.63	"

LABORATORY NOTES. Much of the coal represented by the specimens of the upper bench is very bituminous; the remainder is of dull lustre. It crushes easily, contains much selenite, but little pyrite. The coal of the lower bench is moderately bright, with streaks of bituminous matter; contains considerable shale, selenite and calcite, but little pyrite. Neither coal coked in the porcelain crucible.

This coal is also distinctly to be classed as a bituminous coal. The moisture percentage is to be considered high, and that of the ash also. The amount of sulphur present is moder-

ate for coals of this class and region. Concerning the adaptabilities of the coal for coking and gas production, the remarks just made concerning the Stealey and Fowler shaft will apply here also.

In addition to the mines last described, and closely adjoining them, there are in the Rocky Branch district a number of other drifts and shallow shafts in operation. The coal is in all respects similar in section and character to that last described. These are the mines of the Bolen Coal Co., the Bruce and Knoble Coal Co., the Gunn Coal Co. and the Hagood Coal Co. About two miles southwest of Higginsville, at the shaft named Minershagan on the map, the Jackson and Taggart Coal Co. has recently resumed operations in the Lexington bed. This shaft was abandoned at the time of operation and no measurements of the coal could be made.

THE CONDITIONS OF MINING.

Most of the coal mining in the area has been done in the Lexington bed by the longwall method, and fully seventy-five per cent., if not more, of the coal in the ground is mined and shipped. The nature and the dimensions of the coal bed and associated strata permit of the use of this method of mining to great advantage. A description of the details of such mining as practiced here and in other parts of the State has already been published by the Survey, and will not be repeated here.*

The Mulky bed is of a similar section, and the same method of mining is applicable in it.

The Waverly coal bed is thicker than either of the others, and the character of the roof and floor are different. The pillar and room method will probably prove best for mining this bed, and, in this case, probably not more than 50 per cent. of the coal in the ground can be mined and shipped. It is quite possible, however, that the roof may be of such a character over portions of this bed that the longwall method can be introduced. In this case a much larger percentage of the coal in the ground will become available.

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* Prelimary Report on Coal, 1891, Appendix A, pp. 173-186.

THE AVAILABLE COAL TONNAGE.

The question of the amount of available coal within this area is one of great economic importance. The conditions restricting the distribution and availability of coal beds have already been described in a published report of the Survey,* and will not be further discussed here.

In brief, the two fundamental factors necessary for the calculation are, first the area underlain by each coal bed, and, second, the thickness of the bed. We will now briefly consider these questions with reference to each of the coal beds already described.

The Waverly coal bed, it was seen, is found well below drainage level and lies in a nearly horizontal position; hence, if continuous, it would underlie the entire area of the sheet, which equals 240 square miles. The thickness of the bed at Waverly, in round numbers, is 3 feet. Under the conditions there presented it is probable that not more than half of the coal can ordinarily be mined and shipped, though with careful management a greater yield might be reached in places. Applying this as an average yield, however, with a three-foot bed over the whole area of 240 sq. miles, we get as the total available tonnage about 330 million tons. It is, however, not allowable to assume that this bed extends under the whole area in an available condition. It is probable that under a portion of area of the Warrensburg sandstone it is absent, and it is further probable that it becomes so attenuated or of such inferior quality under other areas as to be unworkable. The records of deep drill holes which have been cited suggest, however, the presence of the bed at several points in our area away from Higginsville. We, therefore, think it justifiable to allow, as underlain by the Waverly coal bed in an available condition, one-fourth of the total area represented on the map, or in round numbers, 95 millions of tons.

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* Preliminary Report on Coal, 1891, pp. 33 to 41.

The Edwards coal bed, as already stated, is recognized at only one point, *i. e.*, at Edwards Station, and we are not in a position to make an estimate of its probable extent. Drill hole records in other portions of the area do not indicate its existence there, though its stratigraphic and hysometric position would allow of its being co-extensive with the area of the sheet.

The Mulky coal bed is better developed immediately south of the area of the Higginsville sheet than within its borders. On the sheet it is best recognized in the southern portion over the country adjacent to Davis creek. Here, as is clearly shown on the map, it occupies a position above drainage level, and hence does not underlie the whole tributary area. It is hypothetically recognized also on Salt creek, and south of Dover on a tributary of Tabo creek, in both localities above drainage level. Over the area of the Warrensburg sandstone the Mulky coal bed has been removed. These conditions reduce the possible area of the bed within the sheet to about 130 square miles. Records of such drill holes as that in the Corder shaft indicate that the Mulky bed is not persistent here, and the failure to find it of workable thickness along the river bluff strengthens this conclusion. We are inclined to think that it is not an available bed over much of the area of the sheet, but we consider 40 square miles a fair allowance for the territory in which it may exist in a workable condition. The thickness of this bed, as worked, is generally about 75 per cent. as the average amount which can be mined and shipped from this thin bed, we have a tonnage of 40 million.

The Lexington coal bed has been most widely operated, and its area is best defined. Its limits are clearly shown on the accompanying map and sheet of sections. As will be there seen, it occupies generally a position near the hill-tops, well above the drainage level; hence it is absent in the larger valleys. This fact naturally diminishes its area, but, in addition, the Lexington bed has been entirely removed over the area of the Warrensburg sandstone, and it is further not recognized to be present for over a mile east of the range line between town-

ships 24 W. and 25 W. This last fact is indicated on the map by the abrupt termination of the horizon line near that position. Allowing for all of these modifying influences, the total area of the Lexington coal bed within the sheet limits is calculated to be 52 square miles.

Within nearly the whole area, thus restricted, it is probable that the coal bed is in a workable condition, and it is with little doubt a liberal concession to reduce the area to 75 per cent. of the whole, or about 40 square miles. An average thickness of this bed here is about 18 inches. An allowance of 75 per cent. can be made for the proportion mined and shipped. Hence the total amount of probably available coal is, in round numbers, 50 million tons.

Summarizing these results relating to the three principal coal beds of the area, we obtain the following table:

	TOTAL POSSIBLE AREAS. *Sq. miles.*	ASSUMED AREAS. *Sq. miles.*	RESULTANT TONNAGES FROM ASSUMED AREAS. *Short ton.*
Lexington Coal Bed	52	40	50,000,000
Mulky Coal Bed	130	40	40,000,000
Waverly Coal Bed	240	60	95,000,000
Total tons			185,000,000

The Tonnage Mined to Date.

Very nearly all the coal mined within the area to date has been from the Lexington coal bed. From the maps of the mines within this area we obtain the following figures of the area exhausted in and up to about the year 1870:

	ACRES
Corder Coal Co's shaft	100
Winsor Coal Co. (west of Higginsville)	66
Excelsior Coal & Coke Co	36
Bolen Coal Co	15
Dover Coal Co	8
Stealey Mines	7
Winsor No. 1 (east of Higginsville)	6
Hagood Mines	4
Bonanza Coal Co	3
Estimated for about 20 small country pits	20
Total resultant	265

Taking 18 inches as the average thickness of the bed, and 75 per cent as the amount shipped, we have about 520,000 tons

as the total amount of coal produced within this area. A comparison of this amount with the figures given in the table on the preceding page shows it to be an almost insignificant fraction of the total amount estimated to be available.

THE CHARACTER AND ADAPTABILITIES OF THE COALS.

The character of the various coals has already been given in the descriptions of the different mines, so far as can be determined from chemical analysis, hand inspection and general observation and inquiry. The limitations of such methods of investigation have already been suggested. We are unable to state at present just how high any one of these coals rank as a steam producer, but we hope to be able to determine this latter by actual experimental test. We know that the coal of the Lexington bed is highly esteemed as a domestic coal, especially some of that mined in the vicinity of Higginsville. The hardness and cleanliness of this coal recommend it clearly for such use. The possibilities of any one of these coals in the direction of the manufacture of coke can only be suggested from the examination thus far made. Laboratory tests and hand inspections are not sufficient to determine the question conclusively; experimental examinations are necessary for this end.

The suitability of a coal for the production of illuminating gas can be determined by an ultimate analysis, but not by proximate analyses such as are given in this report. An ultimate analysis of a coal is a comparatively costly and elaborate work, and is best preceded by the simple proximate analysis which yields certain indications to guide one in determining upon the advisability of proceeding farther with the work. It is a fact that no longer needs demonstration, that the coals of Lafayette county, as well as many other coals in the State, have a sufficiently large pecentage of volatile hydro-carbons to enable them to be used for the production of illuminating gas. The questions as to whether the volatile constituents have an adequate illuminating power, and whether the percentages of deleterious constituents are not too high, remain, to a

great extent, open. That we have any coals equal to the famous Westmoreland coal of Pennsylvania for gas making, is beyond probability. Owing to the high cost of such gas coals in this region, much inferior local coal can, however, compete with them. Thus, coals with a comparatively large amount of ash, and with as much as from three to four per cent of sulphur are used at gas works in the State, and coals of this grade are perfectly adaptable if the illuminating power is sufficient.

The experimental determination of the adaptabilities of the coals of the State is reserved until the work can be applied to coals from all the different districts, so that the subject may receive full treatment, and so that comparative results can be expressed.*

BUILDING STONES.

The building stones of the Higginsville sheet are of quite subordinate importance. The Warrensburg sandstone furnishes near the town of Warrensburg, in Johnson county, excellent material for building purposes, but the stone of this formation as occurring within our area, is of too soft and friable a nature to be generally of value in this connection. At a few points it has been quarried for local uses. Such a one is the railroad quarry described below. Limestones obtained from the beds of this rock occurring immediately above and below the Lexington coal, are used locally in the country for foundations and other similar purposes.

The two following sandstone quarries are the principal ones within our area: †

D. H. Davis quarry: Mr. Davis has a sandstone quarry situated in township 51 N., 24 W., section 18, east half of the northwest quarter.

The quarry has a face about 145 feet long, and exposes vertically, about 12 feet of sandstone. The bed is cut by ver-

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* For further remarks on the adaptabilities of Missouri's coals, the reader is referred to the recently issued Preliminary Report on Coal, 1891, p. 46-47.

† The description of these quarries are extracted from an article by Mr. G. E. Ladd; prepared from notes collected by Mr. Leo Gluck, on pp. 77 and 78 of Bulletin No. 5, Mo. Geol. Survey, 1891.

tical joint planes, which are about five feet apart. Its maximum thickness is 12 feet, but it is usually parted by a bedding plane so that the largest block ordinarily obtainable is about five feet thick. Blocks of stone five by five by four and a half feet in size are readily obtainable, and one of these dimensions may be increased sometimes to 10 feet. The sandstone when dry has a yellow color. When freshly quarried it is brownish, very soft and easily worked. There are numerous ferruginous streaks running through the bed.

About 4500 cubic yards of stone have been removed from the quarry. Of this amount about 1000 yards went to waste. One-half of the remainder was used locally and the other half was shipped away by rail. The following is the section made at the quarry in descending series:

	Feet.	Inches.
Slope of Stripping	1	3
Limestone, blue	1	3
Sandstone	13	
Shale, dark colored, sandy	20+	

Railroad Sandstone Quarry: This quarry is situated just below the mouth of Mulky creek, on the J. C. & B. branch of the Missouri Pacific railway, township 51 N., range 26 W., section 23, middle of the northwest quarter of the southeast quarter. The quarry is 1200 feet long, but the available face is only 750 feet long. The stone is irregularly stained with iron; is soft and easily crumbled. The sandstone is about 20 feet thick, but only the lower 10 feet is workable. The lower part is divided into three layers of equal thickness, which are strongly cross-bedded in places.

The following is the section obtained here, in descending series:

		Feet.
1.	Soil and clay	10
2.	Shale	10
3.	Shaly sandstone	10
4.	Sandstone, the workable part	10

About half a mile down the railway from the Davis quarry, at the locality of section No. V, of p. 26, the sandstone bed shown in that section has been quarried by the railway company for bridge piers. It is of a light gray color and micace-

ous. It appears to be harder than the stone of the Davis quarry. The bed is about five feet thick and can be quarried in blocks of 3 or 4 feet thick up.

South of the Chicago and Alton railway there are several small quarries in Lower Coal Measure sandstone. Such a one is at the outcrop noted on the map near the west line of section 7, township 49 N., 24 W. Here is an outcrop of rock about 5 feet of soft micaceous and ferruginous, buff colored sandstone; it occurs in layers from 6 to 18 inches thick. Other quarries occur in this vicinity which have been worked for local uses, and also for bridge pier stone along the Chicago and Alton railway. The sandstone in the N. E. ¼, of section 23, of township 49 N., 25 W., and that at the north line of section 16, in the same township, has been similarly worked for local uses. All of this stone is, however, of inferior grade, and it is not to be expected that it will lead to the development of an industry of any considerable magnitude.

CLAYS AND SHALES.

The clays of the Higginsville sheet consist of the superficial Quaternary clays of the loess and of the bedded clays interstratified with the rocks of the Coal Measures. The shales are also stratified beds of the latter formation. The loess is very abundant, as will be seen by reference to the preceding section on that formation. It is suitable for the manufacture of building brick and drain tiles of excellent quality. It is at present only used for supplying local demands. The following is a description of the principal brick yards within the areas prepared from notes collected by Mr. Gluck.*

Bird and Company—This firm manufactures common building bricks at Higginsville. They make by hand only, using soil and subsoil to a depth of about two feet for clay. Two up-draft case kiln are used. The product is a rather soft porous brick.

Krumsick, H.—Mr. Krumsick has a brick yard and tile works one-fourth of a mile west of Corder. Work was begun here in 1886. The brick and drain tile are produced. The

* Extracted from Bull. 5, Mo. Geol. Survey, pp. 76 and 77.

plant consists of one Phœnix horse power brick and tile machine, two circular up-draft kilns, sheds, etc. In 1890, about five hundred thousand bricks, and two hundred and twenty-five thousand feet of drain tile were produced.

Neaman, Gottlieb—Mr. Neaman manufactures common building bricks and drain tiles in Alma. The works were established in 1889. The plant consists of a Penfield brick and tile machine, one up-draft case kiln and drying sheds. The clay used is soil and subsoil. In 1890 one hundred and fifty thousand bricks and one hundred thousand tiles were produced.

Shafernolte—Mr. Shafernolte has a brick yard at Higginsville, where he produces common building brick. The bricks are made by a Penfield stiff-mud machine. Two up draft case kilns are used. The clay worked is soil and shale.

The Coal Measure clays generally immediately underlie various coal beds, and partial descriptions of them are contained in the various sections which have been described in the preceding pages. Many of these clays are erroneously termed "fire clays," whereas they are in fact, very far from being such. Samples of such clays have been collected from beneath the coal at the Winsor & Co.'s shaft, east of Higginsville, and at the Dover Coal Company's drift north of Dover. Both of these proved to be highly calcareous, and therefore they would be entirely unsuitable for the manufacture of refractory materials. Some of these clays may prove to be of the proper composition, and others may be valuable, when mixed with other materials, for the production of drain-tile and sewer pipes. Such determinations have, however, not been made by the Survey as yet.

The shale which has claimed most attention so far is the bed immediately below the limestone which underlies the Lexington coal bed at Higginsville. This is of a drab color with darker streaks, is hard, breaking with difficulty with a pick. Beneath the coal, in the Excelsior company's shaft, it is 12 feet or more thick. It contains here small crystals of pyrite disseminated through it and these cause it to be quite fusible. Very hard, vitrified brick have been made from this shale, but

they were also very brittle, due to the ready fusion. For this reason this shale used alone, does not commend itself for use in the manufacture of paving brick. It is not calcareous, at least not sufficiently so to effervesce when treated with acid.

Along Rocky branch, about a mile west of the last, is another bed of shale which has suggested itself for use. It is 5 feet or more thick, and probably underlies the bed above described. This is also of a drab color, but contains no noticeable quantity of pyrite It is, however, highly calcareous, which renders it unfit for general use.

That some of the shales, exposed at various points within the area of the sheet, are suitable for the manufacture of paving brick is to be expected. In fact, any such shales as are not pyritiferous or highly calcareous, or too highly argillaceous can be converted to such use. The work of the Geological Survey in the clays of the State, now in progress will direct attention to the most favorable localities for such developments.

EXPLANATION OF MAP.

The legend of geological coloring and a list of the conventional marks are given on the margin of the map, and need no further explanation. The heavy black lines running vertically and horizontally across the sheet, at intervals of about 6 inches, are range and township lines, inclosing the cadastral township of 36 square miles. The township and range numbers are given in large black figures, just beyond the southern and eastern margin lines of the sheet. The section lines within these townships are represented by fine black lines inclosing squares of about 1 inch length on the side. The meridian and parallel lines are designated by the border lines of the sheet and by the two fine intermediate lines of latitude and longitve. The degree of latitude and longitude of each line is marked on the border. The positions of cross sections are shown by solid blue lines, lettered to correspond with the lettering on the section sheet. Altitudes at various points are designated by red numbers. Black numbers adjacent to drill holes, wells or shafts, designate the depth of the opening, unless a note to the contrary is added The fine broken line termed the horizon line of a coal bed, which runs approximately parallel to the contour line, indicates the limit of the special coal bed.

EXPLANATION OF SECTION SHEET.

The cross sections in the upper half of the sheet, show the profiles and the underground structure along the lines marked on the map, and between the respective points A, B, C, D, etc.—Outcrops, shafts and drill holes adjacent to these cross sections are shown on them in their proper positions, and for ready reference, the positions of towns and the intersections of the cross sections with township, range and section lines are also designated.

The columnar sections of the lower half of the sheet are numbered consecutively and arranged in groups.—The location of each on the map can be determined by reference to the skeleton map in the lower left hand corner of the sheet, where the position of each section is indicated by its special number.—The

exact locations of drills and shafts are given on the large map by name.—Each member of a group is placed vertically in its proper position with relation to a common base line which is drawn across the sheet. The correlation of the strata represented in the different sections, is indicated by fine, broken lines connecting the different members. The members of the group of detailed sections in the lower right hand corner are of coal beds which have been operated at different points. They are on a large scale and show the details which are of importance for successful mining.

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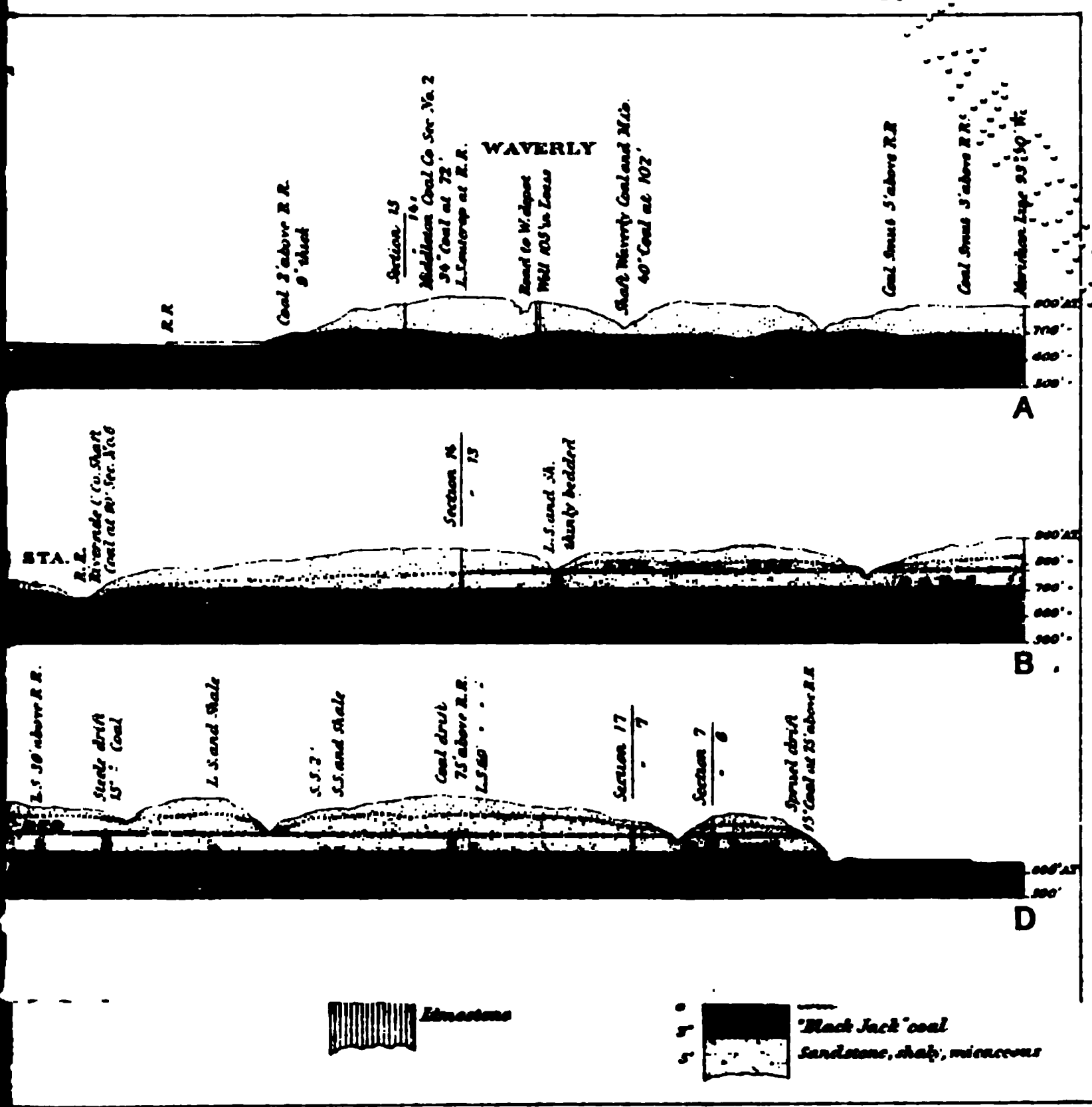
HIGGINSVILLE SHEET

NOTE. *The projection is that of the U S Geological Survey Sheet of 1885-7. The Missouri river is from Surveys made in 1879, by the Engineer Corps of the U S Army*

CONVENTIONAL MARKS.

	Geological Boundary	S H	School House
Drill Hole	Horizon Line of a coal Bed	S h	Shale
ed Drill Hole	Building	S S.	Sandstone
Well	Church	L S	Limestone

To accompany HIGGINSVILLE SHEET



SCALES

General Cross Sections	Hor. Scale	2000 ft. - 1 in
	Vert. "	1000 " - 1 "
Detailed Cross Sections		50 " - 1 "
General Columnar Sections		100 " - 1 "
Detailed Columnar Sections		
Skeleton Map		6 miles - 1 "

GEOLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

SHEET REPORT No. 2.

A REPORT ON

THE BEVIER SHEET

INCLUDING PORTIONS OF

Macon, Randolph and Chariton Counties.

BY

C. H. GORDON, Assistant Geologist.

CONTRIBUTORS:

J. E. TODD, Asst. Geologist.

H. A WHEELER, Asst. Geologist.

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STATE GEOLOGIST.

ARTHUR WINSLOW..... JEFFERSON CITY.

ASSISTANTS.

H. A. WHEELER, assistant geologist.

Specialty: Clays.

C. F. MARBUT, assistant geologist.

Specialty: Detailed Mapping.

J. D. ROBERTSON, assistant geologist.

In charge of office.

T. B. MARBUT, assistant.

PREFACE.

The first of this series of sheet reports, that on the Higginsville sheet, was issued in folio form. The inconvenience for reference of such large sheets of text has led to the substitution of the present form for this and succeeding reports of the series.

The nature and scope of these sheets and accompanying reports have been described in the preface of the Higginsville sheet; all that we wish to emphasize here is that these reports are intended to be as nearly exhaustive and full to descriptive detail concerning the special area as is practicable, and to be correspondingly free from discussion of large questions involving broad inquiry. Hence numerous sections are described in detail, and important results of earlier workers are freely incorporated.

The Bevier sheet proper is entirely the product of the work of the State Geological Survey. The geographic positions of the township and range lines were fixed from previous determinations of latitude and longitude at Glasgow and Columbia, and from a special determination made by the U. S. Coast and Geodetic Survey at Macon City, for which we are indebted to Dr. T. C. Mendenhall, the superintendent. The court-house cupola at that place was located as follows by the final computation:

Latitude of court-house cupola, Macon City.....	39°	44′	32″.27
Longitude (W. of G.) " "	92°	28′	17″.18

From these points of control errors in location of range and township lines were distributed, and upon this base the work proceeded as has already been described.

In drawing the horizon line of the Bevier coal bed on the map, we have gone a little farther than was the case with the Higginsville sheet, and have extended it over areas where the actual presence of a workable coal bed has not been demonstrated. This was done largely as a more definite suggestion to future exploration. But, in making use of these results, the

significance of a "horizon line," and its relations to the actual area of a coal bed, as defined in the Higginsville preface, should be borne in mind.

The great part of the following report is entirely the outcome of Prof. Gordon's labors, as is also the geology of the map and section sheet. The topographic base is a joint product of Prof. Gordon's, Mr. Marbut's and Mr. Shelton's. The articles by Prof. Todd and Prof. Wheeler on the Quaternary geology and clays respectively are the results of independent work in the same area. Mr. J. D. Robertson conducted the analyses of the coals, and also rendered much assistance in proof-reading and indexing of the report.

ARTHUR WINSLOW,
State Geologist.

JEFFERSON CITY, Mo., Oct. 24, 1893.

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REPORT ON THE BEVIER SHEET.

BY C. H. GORDON, Assistant Geologist.

INTRODUCTION.

AREA AND LOCATION—RAILWAYS—TOWNS—INDUSTRIES.

AREA AND LOCATION.

The Bevier sheet comprises the southwestern part of Macon county, and also portions of Chariton and Randolph counties. It is named from the town of Bevier, in the north eastern corner. The area represented by the sheet is a quadrilateral of fifteen minutes extent in longitude and latitude, and covers 230.04 square miles. It is included between the lines 39° 30′ and 39° 45′ of north latitude and lines 92° 30′ and 92° 45′ of longitude west of Greenwich. It is in the central part of that portion of Missouri which lies north of the Missouri river. Its location with respect to county lines is shown in the following diagram:

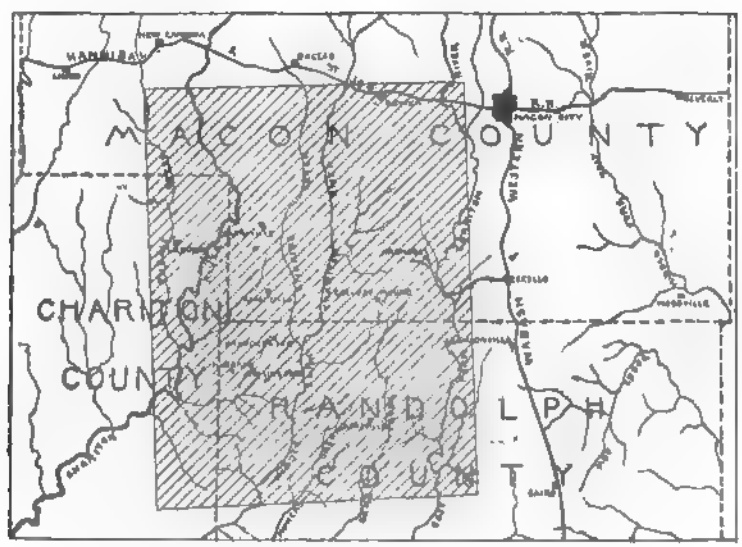

Fig. 1.—Outline map showing the position of the Bevier sheet in Macon and adjacent counties

RAILWAYS.

The only railway, exactly speaking within the area, is the Hannibal & St. Joe road, which enters the sheet at the northeastern corner and passes out at the north before traversing half the distance from east to west. A small branch of the Wabash railway connects Ardmore with Excello for the transportation of coal. Both of these roads are, however, contiguous to the sheet along the whole northern and eastern sides.

TOWNS.

No towns of importance occur within the limits of the sheet.

Bevier is a small town located in the northeastern part of the area on the Hannibal & St. Joe railway. It is a mining town, and one of the oldest in this section. There are nine mines in operation by five different companies. The population of the place, according to the result of the Eleventh census, is 876.

Ardmore is the center of the coal industry in the eastern part of the sheet. It is of recent growth, and its inhabitants consist solely of the operatives of the adjacent mines. It is connected with the Wabash railway at Excello by a switch. The population is not over a few hundred.

College Mound is an old town of inhabitants characterized by no special industries and supported by country trade. It is the center of a rich agricultural region. Its chief interest, however, is centered in McGee College, from which it takes its name.

Darkville consists of a few houses, a church and a store for supplying the local trade.

Thomas Hill is likewise of small dimensions, but has an additional interest in the coal mine which is operated there on a small scale.

Other places are, Rolling Home, Grand Center, Hubbard, Kaseyville, Barryville and Lagonda, which consist, for the most part, of a store and postoffice for the convenience of the surrounding country.

INDUSTRIES.

The industries of the region are restricted to agriculture and coal mining. With some exceptions, all of the sheet included between Middle fork and Chariton river is well adapted to agriculture, and for the most part, is in a good state of cultivation. Between East and Middle forks agriculture gives scant rewards, excepting over the higher portions of the hills. While the chief interest centers in coal, the total value of shipments is only about 68% of that of agricultural products, or about 40% of that of the total shipments. The farm products consist chiefly of hay, fruit, wheat, oats and corn, and, in addition, largenumbers of cattle, hogs and other live stock are raised and shipped. [1]

PHYSIOGRAPHY.

TOPOGRAPHY—HYDROGRAPHY—SOILS—FORESTRY.

TOPOGRAPHY.

The tract included in this report is occupied mainly by the two divides extending from north to south and separating the adjacent valleys of East fork and Chariton rivers, in the order named, from east to west. It includes four plateaus, which may be termed the eastern-border, eastern-central, western-central and western-border areas.

The Eastern-Border Area.—The eastern-border area is limited in extent, including only the western margin of the "Grand Divide," where it is scalloped and ravined by the numerous and widely-branching secondaries of East fork. This stream enters the sheet near the northeastern corner and flows approximately southward, leaving the area for a short distance in the upper half, however. With the steep-bluffed ravines it occupies a strip from two to three miles wide, though its bottoms do not usually exceed three-fourths of a mile in width. At

1 From figures given by the State Labor Commissioner, Hon. Willard C. Hall, in his report for 1891, the value of shipments of various products from railway points in Macon county during the year 1891 was, in round numbers, as follows: Coal, $553,000; cattle, $253,000; hogs, $196,000; horses and mules, $126,000; fruit, 29,000; wheat, $21,000; and hay, $19,000.

Macon City, just beyond the sheet, the altitude of the "Grand Divide" is 890 feet,[1] and from here it slopes gradually southward to Jacksonville, where the altitude is 861 feet. Erosion has reduced thistoward the west, so that the highest points in the strip included within the sheet are about 800 feet A. T.

The Eastern-Central Plateau.—The divide included between East and Middle forks is from five to six miles wide. It is sharply incised along its eastern margin, but broadly scalloped and crenulated, and with longer and gentler slopes, on its western side along Middle fork. The interior is generally well drained by more or less important secondaries, which take their rise in widely-branching dendritic systems, sharply incised in the plateaus. The crest of the divide occupies an irregular line from one to two miles west of the channel of East fork. Its highest point is just east and north of Bevier, on the road to Macon City, where its altitude is 878 feet. It slopes southward within a mile or two to about 850 feet, which altitude it maintains to near the southern limits of the sheet, where it descends to less than 820 feet. The chief drainage is thus seen to be toward the west into Middle fork, though the more important secondaries partake more or less of the general southward flow of the streams of this region. Especially is this true of Claybank creek, in the western-central part of the divide, and of Muncas and Dark creeks, in the southern portion.

The Western-Central Plateau.—This plain is included between Middle fork and Chariton river, and varies from three and one-half to five miles in width. On either side it is bordered by gradually sloping margins, broadly scalloped by the lateral drainage. Gentle slopes constitute an especial feature of its topography. In the southeast only do we find anything corresponding to the abrupt declivities and sharply incised drainage of the eastern areas.

Here, also, we find the highest altitudes at the north (840 ft. A. T.), with a gradual slope to about 760 ft. A. T., near the southern line. At the north the crest line is farthest from Middle fork, which thus drains the largest area, as in the preceding case. But, in the southern half the conditions are reversed, the crest line approaching Middle fork; the principal

[1] The Hannibal & St Joe track in front of the depot is 867 feet; the Wabash Ry. at the crossing of the Hannibal & St. Joe road is 886.5 feet.—Gannett's Dictionary of Altitudes Bulletin No. 5, U. S. Geol. Survey.

drainage, therefore, is westward into the Chariton river. The principal secondary is Morrow creek, which drains the northern central portion, traversing it from north to south, and emptying into Middle fork in the vicinity of Grand Center.

The Western-Border Area.—This area consists of a narrow, pointed tract, bordered on the east by the Chariton valley and terminating on the south near the northwest corner of township 55 N., 16 W. The greatest width of this tract little exceeds two and one-half miles. Along its eastern margin the surface is abrupt and incised by many short, steep and widely branching ravines, which open into the valley of the Chariton river. Its central portion is drained by Puzzle creek, a southward flowing stream emptying into the Chariton river. Along this creek the slopes are comparatively gentle.

Altitudes.—The altitude of the Chariton river valley varies from 650 feet to 690 feet A. T.; that of Middle fork from 675 feet to 740 feet A. T., and that of East fork from 700 feet to 760 feet A. T.

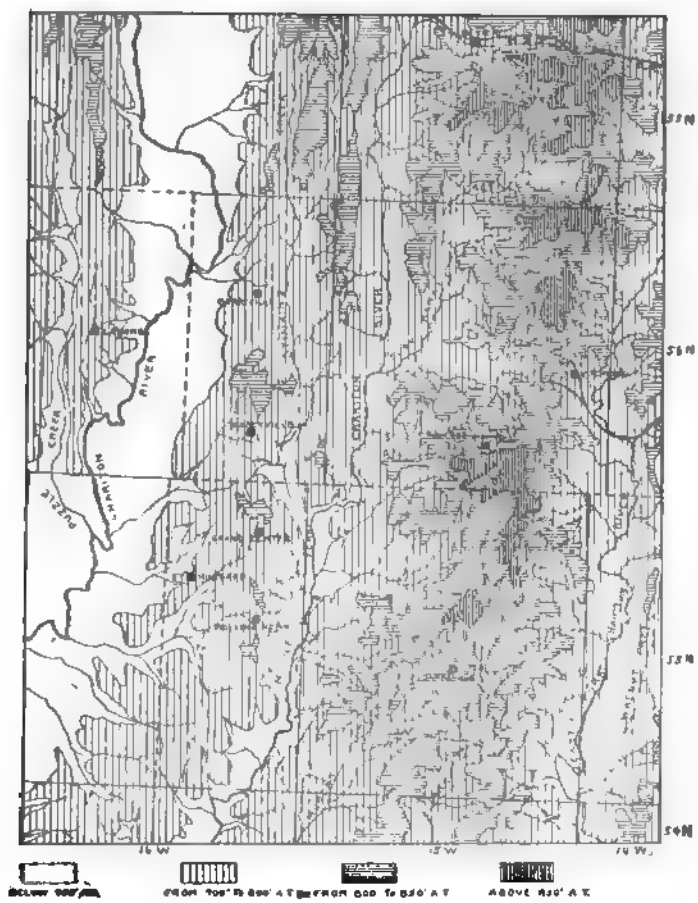

Fig 2 Hypsometric diagram of the Bevier sheet.

TABLE OF ALTITUDES IN THE AREA OF THE BEVIER SHEET.

Locality.	FEET, A. T.
Bevier—railroad track at depot	781[1]
Ardmore—at store on level with opening to No. 26	756[2]
Claybank creek—at bridge, west of Ardmore	713[2]
College Mound—in front of College	840[2]
Darkville	826[2]
Thomas Hill { in front of store	764[2]
Thomas Hill { at Milman's shaft	678[2]
Prairie Hill	725[3]
Rolling Home—in front of store	778[2]
Grand Center—opposite store	777[2]
Hubbard—corner of road	710[3]
Kaseyville—at school-house, one-half mile north of store	781[2]
Barryville—corner of road	780[2]
Lagonda—at store	750[3]
Hammack's Mill—at bridge	685[3]

The distribution of zones of elevation and the general character of the drainage are illustrated by the diagram on the preceding page.

HYDROGRAPHY.

Chariton River.—Chariton river is the stream of chief importance, and receives ultimately the entire drainage of the district. It enters the sheet near the northwestern corner, and, flowing southward, bears gradually westward, cutting the western boundary about four miles north of the southwestern corner. The valley is about two miles wide, usually with gentle slopes on the east and steep declivities on the west. Within this valley the river meanders from side to side, approaching the western bank twice and the eastern once within the limits of the sheet.

The fall of the stream within the limits mapped, is about 30 feet, or an average of about two feet per mile, without taking account of the meanders. Its valley is from 190 to 200 feet below the general summit level of the uplands. At intervals there occur more or less irregularly crescent-shaped ponds or lakes, occupying depressions representing former but long since abandoned channels. They are usually shallow, with

[1] Dictionary of altitudes.—Gannett. Bulletin No. 76, U. S. Geological Survey.
[2] Levelling.
[3] Aneroid barometer

muddy bottoms and reedy margins. The surface of the water is more or less covered with a thick growth of pond lillies. They have usually no outlets, and are supplied with water by the overflow of the main stream and by drainage from the adjacent slopes. The largest of these, Swan lake, occupies nearly a square mile, or one section. These ponds are gradually filling up and drying out, and, were it not for the overflow, would soon cease to exist.

The river channel is from 150 to 200 feet wide, with banks slightly raised about the adjacent bottoms. Portions of these rich alluvial botoms have been brought under cultivation, but the danger to crops from floods renders their cultivation extremely hazardous.

Middle Fork.—This stream is next in importance to the Chariton river, into which it flows at a point not far above where the latter joins the Missouri river. Entering the sheet near the middle of its northern boundary it maintains a southerly course approximately parallel to the Chariton river. The valley, in which it flows alternately from side to side, is about three-fourths of a mile wide, with crenulated marginand usually gradually sloping bluffs. As in the case of the Chariton river, though to a less degree, the width of its valley is greatly disproportionate to that of the stream, which is not over fifty feet wide. The fall of Middle fork is slightly greater than that of the Chariton, averaging about four feet to the mile. The depression is from 140 to 170 feet below the general plain level. Small crescent-shaped ponds and bayous also diversify the valley.

East Fork.—This stream is near the eastern limits of the sheet and occupies a narrow valley with abrupt slopes, sharply incised by narrow V-shaped ravines and widely branching secondaries. The width of East fork bottoms will average about one-half a mile. In this narrow valley the channel meanders from side to side, though it more generally approaches the eastern bluff.[1]

The average fall of the stream is slightly greater than that of Middle fork. The depression of its valley ranges from 120 to 160 feet below the general plain level. The bottoms

1 This is contrary to the statement of Mr. McGee (Trans. St Louis Acad Sci., vol. V, p 508). A reference to the accompanying map, however, will show that the eastern deflections of the channel as compared with its western are about as 9 to 7.

are diversified by small crescent-shaped ponds and bayous, but these are much less frequent, and are smaller in size than those of the preceding valleys.

Secondaries.—No stream of special importance flows into East fork within the limits of the sheet. Numerous small tributaries of high declivity in V-shaped ravines set back into the marginal bluffs. Of these the smaller (and newer) meet the main stream at high angles; while the larger approximate more or less to parallel courses.

Dark creek takes its rise near College Mound, and, flowing southward, enters East fork about two miles east of Clifton Hill.

The western slope of the eastern-central plateau, however, has a more extensive drainage, which is received by several relatively important branches. Of these, the most important are Garrett's branch, Claybank creek and Muncas creek.

Garrett's branch is a comparatively small stream which heads near the northeastern corner of the sheet, flows westward past Bevier and empties into the Middle fork.

Claybank creek is made up of two branches, termed North fork and South fork respectively. North fork takes its rise about a mile southeast of Bevier and joins South fork at a point about three miles northwest of College Mound, from which point the creek takes a westward course and soon enters Middle fork. South fork heads at the summit of the plateau just west of Ardmore. Its course is westward and northward.

Muncas creek heads on the western slope of the plateau near Darkville, takes a southerly course, and empties into Middle fork southeast of Salisbury.

Morrow creek takes its rise in two branches northwest of Callao on the Hannibal and St. Joe railway, flows southward and enters Middle fork near Grand Center P. O. Its banks are characterized by more gentle slopes than is the case with those entering Middle fork from the east.

Puzzle creek enters the sheet at the northwestern corner, flows southward between banks with more or less gentle declivities, and enters Chariton river about two miles northwest of Hubbard P. O. Towards its mouth, the adjoining slopes increase in declivity.

The secondaries have no perennial supplies of water, and are dry except after freshets and during rainy seasons, when they are filled with drainage from the adjacent slopes.

Springs.—Springs are of rare occurrence within the limits of the sheet. Occasionally places are found where limited supplies of water flow out at the junction of a sandstone and shale, but no springs of importance are known to occur in the district.

ANALYSIS OF TOPOGRAPHIC STRUCTURE.

The chief characteristic of this topography is the combination of level plain and varying steep and gentle slopes. The configuration, due entirely to erosion, has been developed upon what was originally evidently an unbroken wide-stretching plain[1]; it illustrates in a striking manner the autogenous[2] type of topography.

The superficial deposits were evidently laid down upon a rock surface already more or less eroded, in a manner similar to the present drainage system, and, while the present drainage is intimately associated with these deposits, and more or less modifies them, the general features of the region were outlined apparently by pre-glacial erosion. In all regions of growing autogenetic drainage it is observed that each considerable tributary may be divided into three portions, in the first of which the declivity is high and the waters do not deposit their detritus; in the second the declivity is less, and deposition results from seasonal and non-periodic variation in stage; while in the third the stream approaches base-level and flood-plain deposition prevails. According to this principle, the relative age of the streams of any particular region may be determined by a comparative study of their valleys.

A study of the valleys of the sheet shows that the Chariton river and Middle fork, with their comparatively wide valleys and meandering channels, are evidently approaching base-level, and erosion is principally directed toward the widening of the valley. In the case of East fork, the narrow valley, more rugged topography, and prevalent V-shaped ravines, show it to be, as yet, in its adolescent and more active stage, though rapidly approaching the condition of the preceding streams.

1 McGee, Trans. St. Louis Acad. Sci., Vol. V., p. 311

2 A term given by McGee to denote drainage developed upon a level or level plain, unaffected by localized orogenic movements, either antecedent or subsequent to the birth of the water-ways. 7th Annual Rep. U. S Geol. Surv., p. 562.

SOILS.

The soils of the region belong, for the most part, to that portion of the glacial deposit commonly denominated "gumbo," which is generally of peculiar tenacity and intractability. Above the bottoms a shallow humus overlies a tenacious and nearly impervious yellow or buff clay, with but little sand. Boulders and pebbles are distributed sparingly through it. Along East fork the soil is poorly adapted for agriculture, though usually supporting a dense but stunted undergrowth.

The bottoms of all the streams support a liberal growth of elms, oaks, etc. The uplands in the vicinity of Darkville and College Mound furnish some excellent farming lands, as does also most of the area between Middle fork and Chariton river. A strip of land several miles wide, extending from Ardmore northwestward across the sheet has suffered much from depletion by erosion, due, doubtless, in some degree, to details of the stratigraphy which will be noticed later. The worst feature of the soils is the tendency to "drown" in wet, and to "bake" in dry weather. This may be obviated to considerable extent by thorough and persistent under-drainage. The introduction of better methods of agriculture will tend greatly to increase the fertility of the soils. In some cases the deterioration of soils may be traced to the injudicious cultivation of cotton and tobacco in early days. Until recently but little wheat has been raised in the county. It has been found to thrive well, however, and is now grown quite extensively and vies with corn as the principal crop. Fruits likewise have been generally neglected, until recently, though apples and other fruits grow well and are now being cultivated assiduously. The wide alluvial bottoms of the Chariton river furnished many acres of rich soil as yet unavailable on account of periodic overflow. They are being gradually occupied, however, though their cultivation is rendered hazardous from high water.

FORESTRY.

The timber is mostly confined to the slopes and valleys along the streams. Along East fork the slopes are generally covered with a profuse though stunted growth of oak of several species, the shingle oak predominating. The bottoms of

Middle fork and Chariton river are occupied by a characteristic growth of elms, oaks and other trees. In the case of the latter stream in the northern portion of the sheet the timber is mostly confined to the western bank, but toward the south it occupies nearly the entire bottom. The steeper slopes of the secondary streams are likewise covered with a varying growth of timber, while that on the gentler slopes has been largely removed for cultivation. The following is a list of trees found growing in the district. Those marked with an (*) are of comparatively rare occurrence:

LIST OF TREES WITHIN THE LIMITS OF THE BEVIER SHEET.

Post Oak or Iron Oak..... *Quercus stellata**
White Oak..... .... *Q.. alba*
Red Oak. .... *Q. rubra*
Pin Oak..... ..... *Q. palustris** (Broadhead)
Quercitron, Yellow Barked or Black Oak..... *Q. coccinea var. tinctoria*
Laurel or Shingle Oak..... *Q. imbricaria*
Swamp White Oak.. ..... *Q. bicolor**
Burr, Overcup or Mossy Oak..... *Q. macrocarpa*
Swamp Post Oak..... . *Q. lyrata**
Glaucus Willow .... *Salix discolor*
Cottonwood or Necklace Poplar..... *Populus monilifera*
Shell-bark or Shag-bark Hickory..... ..... *Carya alba*
Black Walnut..... .... *Juglans nigra**
Sycamore or Buttonwood..... *Platanus occidentalis*
American or White Elm..... *Ulmus americana*
American Crab Apple..... *Pyrus augustifolia*
White or Silver Maple..... *Acer saccharlinum var. nigrum*
Horse Chestnut..... *Æsculus hippocastanum*
Black Ash..... *Fraxinus sambucifolia*
Common Pawpaw..... .... *Asimina triloba*
Water Locust..... *Gleditschia aquatica*
Honey Locust..... .. *G. tricanthos*
Black Haw..... *Viburnum prunifolium*
Wild Black Cherry..... *Prunus serotina*

GEOLOGY.

STRATIGRAPHIC GEOLOGY—STRUCTURAL GEOLOGY—ECONOMIC GEOLOGY.

STRATIGRAPHIC GEOLOGY.

Formations.—Both clastic or stratified rocks and superficial deposits are represented within the area of the sheet. The former belong to the Coal Measure division of the Carboniferous period, and the latter consist of the drift of the first Glacial epoch, and alluvium. The following diagram represents the order and classification of the rocks found within the limits of the sheet.

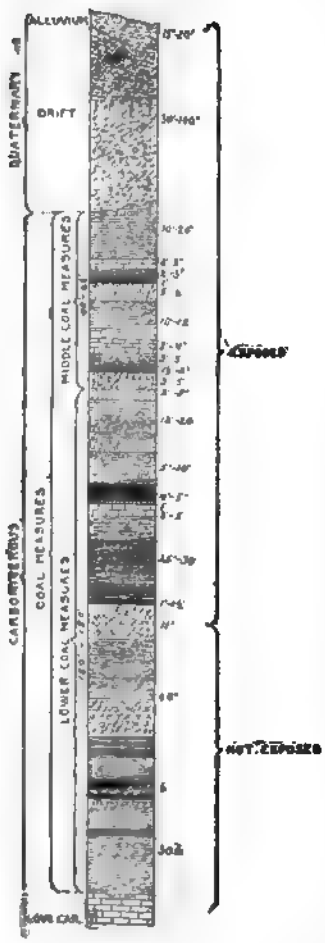

Fig. 3. General section of the rocks of the Bevier sheet.

THE COAL MEASURES.

No clearly recognizable horizon has yet been generally defined for the line between the Lower and Middle Coal Measures of the State, and the separation is here made provisionally at the top of the arenaceous deposit overlying the Bevier coal.[1]

[1] In Swallow's and Broadhead's reports, and in the report of the present Survey on the Higginsville sheet, this line is drawn at the top of a sandstone about 20′ below the Mulky coal bed. From investigations made along the line of the Wabash railway westward from Huntsville, the writer concludes that what has been considered the Mulky bed in the vicinity of Wakenda station is stratigraphically equivalent to the Macon City coal bed of this report. The variable character of the deposit between the Bevier and Macon City coals, however, precludes our drawing any definable line at the same distance beneath this coal as is done further west, since sandstones may and do occur at different horizons within this deposit. We have therefore made the division at the top of this stratum, or near the base of the Macon City coal bed, this being an easily recognized horizon and capable of greater extension than that previously adopted. Moreover, lithologically this definition commends itself for two additional reasons.

(a) The character of this deposit shows that it is essentially a unit, the variation from sandstone to shale being without recognized order. The deposit as a whole, however, is decidedly arenaceous.

(b) The completion of this formation seems to mark a decided change in the conditions attending sedimentation. Below this line shales and sandstones predominate. Calcareous deposits are rare and extremely irregular in structure and occurrence. Following this, however, we find limestones increasingly prevalent, occurring in more or less massive beds, and quite generally persistent. (See report on Higginsville sheet, page 8.)

Exposures within this area are confined principally to the banks of East fork and to the lower portion of Middle fork. Isolated exposures also occur along Claybank creek and west of Chariton river. A large proportion of these outcrops consist of projecting ledges of the limestones overlying either the Macon City or Summit coals, which, owing to their hardness, are well fitted to withstand erosion. Numerous outcrops of both the Bevier and Macon City coals occur in the eastern half of the sheet.

The general character and arrangement of the strata comprising the indurated rocks of this district are illustrated in the following series of sections:

Typical Sections (Eastern).—One of the most important sections obtained is that of the Eureka shaft, which penetrates very nearly the entire thickness of the Coal Measure strata found here. It is located on the Hannibal & St. Joe railway, near the bridge over East fork and about 1½ mile west of Macon City. It is 15 feet above the track, about 35 or 40 feet above the water in East fork, and is 171 feet deep. The following record was obtained from Superintendent E. D. Hillyer:

Section I (No. 3 of Section sheet).

EUREKA SHAFT—MACON COAL COMPANY.

Three miles east of Bevier—Top of shaft about 800 feet, A. T.

	DRIFT AND ALLUVIUM.	FT.	IN.
1.	Soil, *sandy*	9	
2.	Clay, *blue, marly*	8	
3.	Sand	3	
4.	Gravel	1	
	Depth	21	
	MIDDLE COAL MEASURES.		
	Interval to top of Middle Coal Measures about 160 feet.		
5.	Limestone	3	
6.	Shale, *black, fissile*	3	6
7.	Coal (SUMMIT BED)	1	
8.	Clay	7	6
9.	Sandstone	2	6
10.	Shale, *micaceous, sandy*	9	6
11.	Limestone, *hard, blue; known as "Bluestone" by drillers*	3	
12.	Shale, *black, fissile*	4	
13.	Coal (MACON CITY BED)	1	6
14.	Clay	5	6
	Depth	63	

LOWER COAL MEASURES.

		FT.	IN.
15.	Shale, *micaceous, sandy, with some sandstone*	8	6
16.	"Cement rock" (limestone—A. W.)	2	
17.	Shale, *arenaceous*	3	
18.	Coal, with 1′ to 2′ shale seam (BEVIER BED, operated)	2	
19.	Clay		6
20.	Limestone	3	
21.	Shale	2	6
22.	Limestone		6
23.	Shale		6
24.	Limestone	1	
25.	Shale	1	
26.	Shale, *black, fissile*	5	
27.	Limestone		6
28.	Shale	4	
29.	Shale, *black, argillaceous*	7	
30.	Limestone		6
31.	Shale, *black*	5	6
32.	Coal (LOWER ARDMORE BED)	2	
33.	Clay	11	
34.	Sandstone	6	
35.	Shale, *with thin layers of limestone and sandstone*	7	6
36.	Shale, *black, fissile*	5	
37.	Clay	12	6
38.	Shale, *black, fissile*	2	
39.	Shale	8	
40.	Shale, *black, fissile*	3	
41.	Coal *with clay seam from 6″ to 5′* (EUREKA BED, operated)	6	2
	Total thickness	172	4

Interval to base of Lower Coal Measures about 30 feet.

The Missouri, Kansas & Texas Coal Co.'s shaft, No. 46, is situated 1½ miles southeast of Bevier, on elevated ground. The following interesting section was kindly supplied by the superintendent, Mr. J. R. Braidwood:

Section II (No. 2 of Section sheet).

RECORD OF SHAFT 46.

One and one-half miles southeast of Bevier.

Altitude of top of shaft about 860 feet A. T.

		FT.	IN.
1.	Drift Clay, *reddish yellow*	20	
2.	Clay, *hard, reddish yellow*	45	
3.	Clay, *hard, blue*	41	
	Depth	106	

MIDDLE COAL MEASURES.

Interval to top of Middle Coal Measures about 150 feet.

		FT.	IN.
4.	Shale	9	6
5.	Limestone (*"Iron band rock" of record*)	2	6
6.	Shale, *black, fissile*	2	
7.	Coal (SUMMIT BED)	1	
8.	Clay	6	
9.	Shale	10	
10.	Limestone	4	
11.	Shale, *black, fissile*	4	
12.	Coal (MACON CITY BED)	2	
13.	Sandstone and shales	16	6
14.	Coal (BEVIER BED, operated)	4	3
	Total thickness	167	9

Interval to base of Lower Coal Measures about 100 feet.

A deep drilling was made by the Oakdale Coal company at Bevier during the summer of 1891, but no record of this hole could be obtained bythe Survey.

At Ardmore numerous exposures occur, principally of the Lower Coal Measure rocks. In sinking an air-shaft to No. 26, on the hill above the store, other rocks were penetrated, and the results obtained here from the workmen, combined with some surface exposures, furnish the following section:

Section III (No. 5 of Section sheet).

RECORD OF AIR-SHAFT TO NO. 26 AND EXPOSURES AT ARDMORE.

Altitude at top of shaft 818 feet, A. T.

	DRIFT.	FT.	IN.
1.	Clay, *red and yellow*	34	

MIDDLE COAL MEASURES.

Interval to top of Middle Coal Measures about 180 feet.

2.	Shale, *arenaceous*	6	
3.	Limestone, *hard, blue*	4	8
4.	Shales, *argillaceous above, black and fissile below*	4	
5.	Coal (MACON CITY BED)	6 to 18	
6.	Clay	2	
	Depth	52	

LOWER COAL MEASURES.

		FT.	IN.
7.	Shales, *micaceous, sandy, with intermittent limestone masses and shales, sometimes lithified*	20	
8.	Coal (BEVIER BED, operated)	4	
9.	Clay	1	
10.	Concealed	22	
11.	Shales, *black, fissile*	3	
12.	Coal (LOWER ARDMORE BED)	1	6
	Total thickness	103	6

Interval to base of Lower Coal Measures about 90 feet.

Nos. 11 and 12 of above section were observed in the bank of East fork in two places, one near the bridge and the other near Walter's bank. The thickness of the Lower Ardmore coal was not observed, but is here given on the authority of McGee.[1]

At Thomas Hill a shaft has been sunk to the Bevier coal. The top of the shaft is but a few feet above the adjacent bottoms of Middle fork. On the hill above is an outcrop corresponding to the summit coal and overlying shale and limestone of the general section. These combine to give the following section:

Section IV (No. 9 of Section sheet).

RECORD OF THOMAS HILL SHAFT AND OUTCROPS.

Elevation at top of section about 692 feet A. T.—Shaft begins 17 feet below top of section, at 675 feet A. T.

MIDDLE COAL MEASURES.

Interval to top of Middle Coal Measure about 170 feet.

		FT.	IN.
1.	Limestone, *compact*	3	
2.	Shale, *black, fissile*	2	
3.	Coal (SUMMIT BED)	1	6
4.	Concealed, *probably shales*	13	
5.	Limestone, *yellowish gray*	3	
6.	Clay	3	6
7.	Shale, *black fissile (horizon of Macon City coal)*	1	6
	Depth of shaft	27	6

LOWER COAL MEASURES.

8.	Sandstone, *micaceous, friable*	8	
9.	Shale, *arenaceous*	23	6
10.	Shale, *black*		6

[1]Geology of Macon Co.—Trans. St. Louis Acad. Sci., Vol. V, p. 323.

		FT.	IN.
11.	Coal, *6" clay seam, 1 1-2 feet from bottom* (BEVIER BED).....	4	6
12.	Clay.....	1	6
13.	Limestone, *nodular*.....	?	
	Total thickness.....	65	6

Interval to base of Lower Coal Measures about 120 feet.

The shaft is owned by Mr. Milman, whose son furnished the above record. It is noticeable that there is no coal here at the horizon where we would expect to find the Macon City bed. Its absence here is doubtless due to a local thinning out. The only exposures between Middle fork and Chariton river are isolated ledges of the Middle Coal Measure limestones. West of the Chariton, in the vicinity of Hammack's mill, a section was obtained by G. C. Broadhead,[1] which, supplemented by recent observations, is as follows:

Section V (No. 7 of Section sheet).

HAMMACK'S MILL SECTION.

Altitude at top about 725 feet, A. T.

MIDDLE COAL MEASURES.

Interval to top of Middle Coal Measures about 190 feet.

		FT.
1.	Limestone.....	3
2.	Smut.....	1
3.	Concealed.....	3 to 6

LOWER COAL MEASURES.

4.	Sandstone, *micaceous, brown, soft*	8
5.	Shales, *green, blue and olive, sandy; have slaty cleavages and contain ferruginous concretions; dark vegetable stains are seen*.....	24
6.	Sandstone, *thickly bedded, brown, micaceous*	11
	Total thickness	53

Interval to base of Lower Coal Measures about 120 feet.

The above comprise all the sections obtained, embracing both the Lower and Middle Coal Measure strata. Following is a more detailed discussion of each division.

THE LOWER COAL MEASURES.

General character and thickness—The area in which the Lower Coal Measure rocks appear at the surface is shown upon the accompanying map. It will be seen that they are con-

[1] Report of Missouri Geological Survey, 1855-1871, p. 97.

fined principally to the valleys of the streams, having been brought to light by the denudation of the overlying strata. The total thickness of this division is between 140 and 180 feet. It is composed principally of shales and sandstones, with occasional but irregular beds of limestone. Though the area exposed is comparatively limited, its economic importance far exceeds that of the succeeding division, since it is here that the most productive coal-beds occur. There are three of these, the thickest and most important being the uppermost, or Bevier bed, from which nearly all the coal mined in the district is obtained.

A reference to the preceding general section (Fig. 3) will show the character and succession of the beds constituting this division. From a stratigraphical standpoint some of these beds are deserving of a more detailed description than they have yet received.

Lagonda Sandstones and Shales.—We have thus designated the arenaceous deposit, varying from 18 to 50 feet in thickness, immediately overlying the Bevier coal and constituting the uppermost division of the Lower Coal Measures. It is named from the Lagonda postoffice, in the vicinity of which, at Buster's quarry, and farther north at Hammack's mill, it has its greatest development. We have already noted (p. 11) some of the characteristics of this deposit, and will refer to it only briefly here. This formation is especially remarkable for its variable character and sudden transition from shale to soft micaceous sandstone. It is frequently marked by the casts of stems of sigillarids and calamites, fern leaves, etc. Towards the east this deposit is usually about 18 to 20 feet in thickness and generally more or less shaly, seldom showing sufficient traces of lithification to entitle it to be called a sandstone. As traced westward, however, it not only increases noticeably in thickness, but exhibits a greater tendency to become indurated. This is manifested more often by the development of two sandstone horizons, separated by a considerable thickness of characteristic shale. At the Eureka shaft only two feet of indurated rock were found, while at the Black Diamond shaft, a little more than four miles west, the coal is overlain by four feet of hard, white sandstone; and above this, and separated from it by 10 feet of shale, is another bed of hard, yellow sand-

stone two feet thick. It is noticeable that the deposit has increased from 19 to 25 feet or more. Still farther westward, on the Chariton river, at Hammack's mill, the deposit has increased in thickness to 43 feet, and probably more, having two beds of soft sandstone, of 11 and 8 feet respectively, separated by 24 feet of the shale. This middle portion sometimes shows the presence of limited and non-persistent calcareous concretions, usually in the form of irregular nodular masses of hard blue limestone.

Bevier Coal—This name is applied to the "four-foot seam" of coal immediately underlying the last described stratum, and is so named from the town where it was first developed, and where it is still extensively mined.[1] Each of the coal-beds occurring within the district possesses certain characteristics by which it may be recognized, though in the case of the Summit and Lower Ardmore coals correlation is sometimes a little doubtful unless their relation to other coals is known. The Bevier and Macon City coals, however, the most important, are also most readily recognized.

The following are the means relied upon for their determination:

1. Character, thickness, and sequence of the coals and their associated strata.

2. Altitudes taken in connection with the structural features of the region.

What these structural features are will appear farther on. By reference to the sections of this report it will be noted that the Bevier coal is characterized as follows:

By an overlying arenaceous deposit.....	18 to 50 feet thick.
By a coal bed with clay parting.....	4 to 5 " "
By an underlying limestone.....	3 to 5 " "

This may be considered the key to the identification of this coal. Further discussion of this coal bed will appear under the head of Economic Geology.

Ardmore Limestone.—This is an irregular, marly and concretionary limestone underlying the Bevier coal, and separated from it by from 6 to 18 inches of clay. It appears in numerous exposures in the vicinity of Ardmore. It is generally per-

[1] The amount shipped from the new mining town of Ardmore is now considerably greater than that from Bevier, as shown in the Labor Commissioner's report.

sistent and probably co-extensive with the associated coal. Examinations beyond the limits of the sheet southwestward indicate its presence outside of the area where the Bevier coal is known to exist. The limestone is quite fossiliferous, usually abounding in *Spirifer cameratus*, *Athyris subtilita*, *Chonetes mesaloba*, *Productus costata*, Zaphrentis and other forms. The lower layers are commonly more regularly stratified, while the upper consist, for the most part, of irregular concretionary nodules of limestone imbedded in a marly clay.

Lower Ardmore Coal.—The Ardmore limestone described above is underlain by from 25 to 30 feet of argillaceous and bituminous shales, sometimes sandy, and with a few thin beds of limestone interstratified. In the shales above the coal intermittent beds of bituminous limestone frequently occur. The coal of this horizon is the lowest exposed in the vicinity of Ardmore. No known outcrops are found outside of the valley of East fork. It is overlain by from five to six feet of black fissile shale containing ovoid nodules. These have given occasion for the mistake of identifying this shale with that overlying the Macon City coal, where similar nodules also occur;[1] but in the latter case they are usually larger and more conspicuous. The shales seem generally to be overlain by limestone from six inches to three feet thick, but its prevalence was not satisfactorily demonstrated. At the Eureka shaft 11 feet of clay is reported underlying the coal. The coal is sometimes divided by a varying thickness of clay and shale. No attempt has been made to mine this coal, as it does not seem to promise profitable results.[2] A discussion of its economic value is therefore omitted, as is also that of the Summit coal, for a like reason.

Eureka Coal.—There are no exposures of the strata below the Lower Ardmore coal within the limits of the sheet, and our only knowledge of these is based upon the record of the Eureka shaft. That record shows the clay underlying that coal to be followed by 44 feet of alternating beds of sandstone, shale and clays, below which is a seam of coal of doubtful extent and

[1] See Geology of Macon County, by Wm. J. McGee. Trans. St. Louis Acad. Sci., Vol. V. pp. 322 and 323; also sections 7, 8 and 10 on plate.

[2] At Eureka shaft an entry is now being driven to ascertain if it can be worked with profit. Report State Mine Inspector 1891, p. 54.

divided into two benches by a clay seam varying in thickness from six inches to five feet. The coal is impure and roof poor. The full bed is about 6 feet thick, of which 3½ feet is coal. This is the only known occurrence of this coal, and is probably a local deposit. The deep drilling made at Macon City shows no coal at this horizon.[1] Some attempt has been made to operate this bed here, but it has not been attended with success, owing largely to the poor character of the roof.

The following sections include the exposures of Lower Coal Measure rocks seen within the sheet. Additional details appear in the preceding typical sections and under the economic discussion of the Bevier coal.

East Fork Sections.—In the northern part of the sheet no exposures of the Lower Coal Measures appear along East fork. A general section representing the exposures at Ardmore is given on page 16. At several places northeast of the store the Ardmore limestone and Lagonda shales outcrop along the stream. About half a mile northeast the shales overlying the Lower Ardmore coal appear in the west bank of the stream. G. C. Broadhead gives a section from this locality, which is here inserted:

Section VI.

SECTION ON EAST FORK,

One-half mile northeast of Ardmore (S.W.¼ N.W.¼, Sec. 19).
Altitude at top of section about 755 A. T.

		FT.	IN.
	Interval to top of Lower Coal Measures about 20 feet.		
1.	Slope, *concealed*	3	
2.	Limestone, *thick bedded, bluish gray; breaks in nodular masses.*	2	6
3.	Slope, *concealed.*	12	
4.	Shales, *bituminous, contains a bed of limestone.*	4	
5.	Coal (LOWER ARDMORE BED)	1	4
6.	Clay, *blue*		1
7	Concealed	2	6
8.	Shales, *bituminous*	1	6
9.	Coal	1	2
10.	Clay, *yellow*	1+	
	Total thickness	29	1

Interval to base of Lower Coal Measures about 90 feet.

[1] This hole was put down to a depth of 1000 feet. It shows 185 feet of Coal Measure strata in which there is a noticeable absence of all the coals below the Macon City bed.

The limestone (No. 2) of this section is evidently the Ardmore limestone, while the coal and interbedded shales below represent the Lower Ardmore coal. The base of the section is at the surface of low water in East fork.

Just above this locality the Bevier coal is worked at Walter's bank. Its altitude is here 755 feet, showing that it comes in immediately above the preceding section. It is here four feet thick and is overlain by sandy shales.

At the Ardmore bridge over East fork, black shales, said to be underlain by coal, appear in the bed of the stream McGee[1] gives the following section from this locality:

Section VII.

ARDMORE BRIDGE SECTION.

		FT.	IN.
1.	Drift	10	
2.	Limestone, *heavy, bedded in discontinuous ledges, generally pure but sometimes magnesian*	4	
3.	Shale, *thinly and smoothly laminated, with ovoid nodules*	5	
4.	Coal (LOWER ARDMORE BED)	1	6
5.	Fire-clay, *light blue, extending to bottom of channel*	3	

This coal probably represents the upper bed, No. 5, of Section VI. The thickness of the limestone, No. 2, is accepted with doubt.

At the railway cut three-fourths of a mile south of Ardmore, a ten-inch layer of limestone, underlain by 10 feet of clay shales filled with iron nodules, is seen. The Bevier coal comes in several feet above this. Farther on tumbled masses of limestone appear at the side of the track, apparently derived from the Ardmore limestone.

On the road to Excello, the Lagonda sandstones and shales appear in the hillsides at several places. South of Ardmore the Bevier coal has been drifted into at numerous points along both sides of the stream. Most of these localities are indicated upon the map, and need not be described here.

On Beecher creek the Bevier bed appears in the bed of the creek, in the following section:

[1] Trans St. Louis Acad. Sci., Vol. V., p. 328.

Section VIII (No. 6 of Section sheet).

BEECHER CREEK SECTION (N. E. ¼ N. E. ¼, SEC. 2).

Altitude at top of section about 790 A. T. Interval to top of Lower Coal Measures about 16 ft.

		FT.	IN.
1.	Shales, *sandy*. Exposed	3	
2.	Coal, *more or less broken and disturbed; with included clay masses; conspicuously slickensided and containing pyritiferous masses filled with wood impressions*	4	6
3.	Concealed (about)	4	
4.	Limestone, *nodular with fossils*. Exposed	2	
5.	Shales, *sandy*. Exposed	2	
	Total thickness	15	6

It is noticeable that the altitude of the coal is here considerably greater than at Ardmore.

About two miles southeast of this, in the N. E. ¼ Sec. 6, the Lower Ardmore coal appears somewhat above the level of the East fork; it is here 18 inches thick. About three-quarters of a mile southwest is an abandoned drift on the same horizon.

In the southeastern corner of the sheet, at J. T. Cooley's drift, A. Winslow obtained the following section of the air-shaft:

Section IX.

J. T. COOLEY'S DRIFT (S. E. ¼, N. E. ¼, Sec. 5).

Altitude at top of Shaft about 756 ft. A. T.

		FT.	IN.
1.	Soil	2	
2.	Limestone	1	6
3.	Shale, drab	16	
4.	Coal, with 2-inch parting (BEVIER BED)	4	
	Total thickness	23	6

About a mile northeast of this, a well at 775 ft. A. T. gave the following section:

		FT.	IN.
1.	Soil and decomposed limestone	3	
2.	Shale, *black, fissile*	5	
3.	Coal (MACON CITY BED)	1	6
4.	Fire-clay to bottom of well	1	6
	Total thickness	11	

This last section was taken outside the limits of the sheet, but is inserted here to supplement the preceding.

Middle Fork Sections.—In the upper part of the sheet no exposures were observed along Middle fork.

At Bevier the coal is reached at from 50 to 160 feet, according to the location of the shaft. The general character of the Lower Coal Measure strata here may be seen by reference to Section II, page 15.

At Loomis and Snively's shaft No. 4, the drill was put down 21 feet below the coal, with the following results:

Section X.

RECORD OF LOOMIS AND SNIVLEY'S SHAFT No. 4 (¼ mile east of depot).
Altitude at top of shaft about 785 feet A. T.

		FT.	IN.
1.	Old shaft; no record, coal at bottom, with ½ inch clay seam averaging 4 feet in thickness	52	
2.	Clay	1	
3.	Limestone, *irregular*, *nodular*	2	6
4.	Shale, *gray*, *argillaceous*	2	6
5.	Shale, *dark gray*, *harder than No. 4; somewhat laminated*	15	
	Total thickness	93	

Interval to base of Lower Coal Measures about 110 feet.

There is apparently a local dip here to the west, while toward the south the coal rises for about a quarter of a mile and then descends again. There is also a rise toward the north.

The Black Diamond Coal company's shaft is situated about a mile and a half southwest of Bevier, and is connected with the Hannibal & St. Joe railway by a switch. The books of the company furnished the following record:

Section XI (No. 1 Section sheet).

RECORD OF BLACK DIAMOND SHAFT.
Altitude at top of shaft about 790 feet A. T.

		FT.	IN.
1.	Soil, *black*	2	
2.	Clay, *yellow*	10	
3.	Clay, *red joint*, *hard*	4	
4.	Clay, *very hard*, *dark blue*	5	
5.	Clay, *blue*, *softer*	17	
	Depth	38	
	LOWER COAL MEASURES.		
6.	Shale, *arenaceous*	9	
7.	Sandstone, *hard*, *yellow*	2	
8.	Shale	10	
9.	Sandstone, *hard*, *white*	4	
10.	Coal (BEVIER BED)	4	7
11.	Clay		10
12.	Limestone, *hard* (*sump*)	4	6
	Total thickness	72	11

Interval to base of Lower Coal Measures about 115 feet.

The shaft apparently penetrates the hard rocks which constitute the upper strata of the Lower Coal Measures.

Following is a tabulated list of the mines operating the Bevier coal at Bevier:

BEVIER COAL MINES.

Number.	Name of mine.	Location.	Altitude at top of shaft, A. T.	Depth to bottom of coal.	Altitude of coal, A. T.	Remarks.
	Mo. Kan. & Tex Coal Co.:		Ft	Ft	Ft.	
1	Shaft No 42	Center Sec 16	845	118	727	
2	Shaft No 48	NW ¼ NE ¼ Sec 21	845	133	712	
3	Shaft No 46	SW ¼ NW ¼ Sec. 24	860	168	692	See Sec. II, p. 15
	Loomis & Snively Coal Co.:					
4	Shaft No 1	NW ¼ SE ¼ Sec 15.	780	62	718	
5	Shaft No. 3	SE ¼ NE ¼ Sec 16.	780	72	708	
6	Shaft No. 4	SE ¼ NE ¼ Sec 15.	785	52	733	See Sec. X, p. 25
7	Oakdale Coal Co.	SW ¼ NW ¼ Sec 15	775	60	715	
	Watson's Coal and M. Co.:					
8	Shaft No 1	NW ¼ SE ¼ Sec 16	805	76	729	
9	Black Diamond Coal and Mining Co	SE ¼ SW ¼ Sec. 16	790	73	717	See Sec. XI, p. 25

Mr. Thos. Francis reports that a drilling made in Middle fork bottoms, about one and three-fourths miles west of Bevier, showed coal to be absent. The altitude of the bottoms is about 735 or 740 feet here. The horizon of the coal is from 10 to 20 feet below this. As the thickness of the alluvium will probably equal this amount, the absence of the coal may be readily attributed to erosion.

At Shacknicht's, three and one-half miles south and half a mile west of Bevier, a shaft reaches the coal at 50 feet from the surface, where the altitude is about 795 feet.

At Terrell's bank, three-fourths of a mile west, the same seam is drifted into in the bank of the creek at an altitude of 740 feet. One and a quarter miles south some abandoned pits, at an altitude 755 A. T., indicate former workings in this bed.

A section by McGee, on the Bevier and College Mound road, which was evidently taken in this vicinity, is as follows:

Section XII.

CLAYBANK CREEK SECTION—McGee.[1]

	FT.
1. Sandstone, *heavy bedded, sometimes incoherent*	4
2. Shale or clay, *arenaceous*	1

[1]Trans. St. Louis Acad Sci. Vol. V p 324

		FT.
3.	Coal (Bevier Bed)	5
4.	Clay and slope, about	5
5.	Limestone, *brown, ferruginous, dolomitic*	2
6.	Limestone, *heavy bedded, with conchoidal fracture, sometimes argillaceous, with shaly partings*	3
7.	Shale, *light-blue, rapidly breaking down into clay*	11
	Total thickness	31

"It is noteworthy that in the half or three quarters of a mile of more or less imperfect exposures combined in this section, there is a westward dip amounting to not less than 30 or 40 feet."

Near the bridge over Claybank creek, about three miles northwest of College Mound, 18 inches of coal is reported on the land of J. D. Baker. He has tested with a drill below this, passing through 35 or 40 feet of argillaceous shale, becoming more sandy below, but found no coal. The exact locality was not ascertained. Sandy shales appear in the bank just above the bridge, at an altitude of about 720 feet. We correlate Baker's coal with the Lower Ardmore bed. At two points about one-half a mile east of this, black fissile shales, probably representing those overlying the above coal, were observed at the edge of the bottoms, on C. Sherman's land.

At Powell's bank, one and one-half miles east of this, on a branch of Claybank creek, the Bevier coal is exposed, overlain by 10 feet of sandy shales. The coal shows evidence of more or less disturbance similar to that on Beecher's creek (p. 24). G. C. Broadhead visited this locality in 1855, and gives the following, which is a more complete section than could be obtained at the time of our visit:[1]

Section XIII.

Exposure at Powell's Bank (S.E.¼, S.E.¼, Sec. 15).

After Broadhead.

		FT.	IN.
1.	Soil, with drift-clays underneath		
2.	Shales and sandstone, *brown and cream-colored; micaceous*	3	
3.	Shales, *dark, bituminous, pyritiferous, contains productus æquicostatus*	2	
4.	Coal (Bevier Bed)	5	9
5.	Fire-clay, *a few inches*		
6.	Limestone, *blue, nodular, in bed of creek*		

[1] Report Mo. Geological Survey, 1855-71, p. 84.

About three-fourths of a mile south of this the seam is reported to be seven feet thick, and has been drifted into for local use on the land belonging to Gould Richmond.

The next exposure of the Lower Coal Measure strata is at Hein's and Hudson's shaft, about four and one-half miles southwest of College Mound. Here the Bevier coal is reached at a depth of 12 or 15 feet.

About a mile and one-half southwest, at Beard's drift, the same bed outcrops at about 725 feet A. T. It is here six feet thick, with a 13-inch dirt seam. This drift is situated within a small ravine, opening into Middle fork bottoms. About 1000 feet southwest the following section was measured by Mr. C. F. Marbut in the bank of the creek:

Section XIV.

IN EAST BANK OF MIDDLE FORK (S.E.¼, N.W.¼, Sec. 18).

Altitude top of section about 705 ft. Interval to top of Lower Coal Measures about 55 ft.

		FT.
1.	Limestone, thickness not seen.	
2.	Shale, *black*, *fissile*	4
3.	Clay, *black*, *carbonaceous*	4

This section evidently represents the horizon of the Lower Ardmore coal. About half a mile northwest of this locality four feet of coal is reported by Mr. Marbut, at the horizon occupied by No. 3 in the above section. About a mile south of Beard's drift, coal has been drifted into at an elevation of about 720 feet. A section measured here by Mr. A. Winslow [1] shows the following succession:

Section XV.

OUTCROP NORTHEAST OF THOMAS HILL.

		FT.	IN.
1.	Shale, *arenaceous*	10	
2.	Coal	3	6
3.	Clay and shale parting		2 to 6
4.	Coal	1	6
5.	Clay	4 to 5	
	Total thickness	10	6

At Thomas Hill an instructive exposure of the Lower Coal Measures is seen in the record of Milman's shaft (p. 17).

The Lower Coal Measures do not appear at the surface west of Middle fork within the limits of the sheet, except at

[1] Preliminary Report on Coal, Mo. Geological Survey, 1891, p. 69.

Hammack's mill[1] and near Lagonda, where sandstones and shales appear in the strike of the College Mound axis.

A shaft put down at New Cambria showed 68 feet of sandstone and shales at this horizon, underlain by one foot of coal. Then 40 feet of rock was passed through, followed by a 4-inch discontinuous seam of coal. From this point a drill-hole was put down 88 feet, reaching a hard rock at 296 feet from the surface, and the work was stopped after penetrating this rock a distance of 14 feet.

THE MIDDLE COAL MEASURES.

East of Middle fork, the rocks of the Middle Coal Measures are at higher levels excepting near the northern and southern limits, as will appear farther on. West of Middle fork these rocks extend over nearly the whole area, excepting the river bottoms, though they are, for the most part, concealed from view by a heavy capping of drift. They originally extended over the whole sheet, but have lost much by the erosion of the streams and their tributaries, bringing to view the rocks below. The importance of this division is enhanced by the fact that it contains the second and only remaining productive coal bed within the district. This division of the Coal Measures is represented here by from 30 to 40 feet of shale and limestone, with two beds of coal.

Macon City Coal.—This coal lies from three to five feet above the top of the Lower Coal Measures, from which it is separated by that thickness of clay. It is mined to some extent at Macon City and also along the Chariton river. It is characterized by a capping of shale and limestone as follows:

Limestone, *hard*, *blue*	3 to 4 feet
Shales, *black*, *fissile*	2½ " 5 "
Coal	1½ " 3 "

Usually the coal is from 18 to 22 inches thick. The overlying shale generally contains nodular concretions varying from 6 to 20 inches in diameter. A part of the fissile shale is sometimes replaced by clay or soft argillaceous shale. The limestone is especially characterized by its hardness and ability to resist erosion. Hence it is frequently seen projecting from the hillsides in massive ledges. It is quite highly fossiliferous,

[1] The section at Hammack's Mill is given on page 18. See, also, No. 7 of Section sheet.

as are also some parts of the underlying shale. Owing to the hardness of the rock, however, fossils are not easily obtained from the limestone. The characteristics of the Macon City coal and its associated beds are so constant as to make these strata especially valuable for purposes of correlation.

We have traced these rocks westward as far as Wakenda station, on the Wabash railway, where they present almost identically the same appearance as in Macon county. The bed at Wakenda has been identified as the Mulky bed of Lafayette county.[1]

Summit Coal.—This is the highest coal seen, and is separated from the limestone overlying the Macon City bed by from 15 to 20 feet of sandy and argillaceous shales and clays. These shales seldom become sufficiently indurated to be termed sandstones. The thickness of the coal is seldom more than a foot. The following is the characteristic succession of strata:

Limestone, *hard*, *blue*	1 to 2½ feet.
Shale, *black*, *fissile*	2 to 3 "
Coal	10 to 13 inches.

It will be noted that we have here a recurrence of conditions similar to those under which the Macon City coal is found, and it is frequently the case that, in isolated exposures, no distinction can be made between these beds. Sandy shale overlies the Summit limestone, succeeded upward by limestones, though these latter were not observed within the limits of the sheet.

In addition to the representation of these rocks shown in the preceding typical sections, the following sections of Middle Coal Measure rocks are given:

East Fork Sections.—At the Macon-Bevier bridge, three miles east of Bevier, limestone and shale appear in the west bank of the stream. McGee gives the following section from this place, which is somewhat fuller than the one we were able to obtain:

[1] Broadhead.—Report of 1872, page 60. The section given by Broadhead in this report occurs at Hardwick's mill. At a point near the bridge, north of the station, the limestones and shales of two coal horizons appear in the bluffs. The lower coal occurs a short distance above a massive sandstone (which is quarried to some extent here), and presents the usual appearance of the Macon City coal. It can be traced westward along the bluffs to Hardwick's mill. Between these points it shows a decided westward inclination. The sandstone seen below is apparently the stratigraphical equivalent of that quarried a few miles east, at White Rock.

Section XVI (McGee).

AT MACON-BEVIER BRIDGE (S. W. ¼ N. W. ¼ Sec. 18).
Altitude at top of section about 765 feet A. T.
Interval to top of Middle Coal Measures about 160 feet.

		FT.
1.	Limestone, *compact, generally pure, but sometimes slightly magnesian, containing no good fossils, but occasional traces of shells. In one or two heavy ledges*	3
2.	Shale, *thinly laminated, black, fissile*	3
3.	Slope, about	15
4.	Limestone, *irregularly bedded, knobby, with abundant Producti*	2
5.	Slope to bottom of channel	1
	Total thickness	24

Interval to base of Middle Coal Measures about 15 feet.

We would correlate this section with Nos. 11 to 16 of the Eureka shaft (See p. 14.). The shales shown here (No. 2) appear in the bank just south of the railway bridge, while still farther down the stream the limestone (No. 4) appears at the water's edge. About half a mile southwest of the railway bridge the following section appears in a ravine:

Section XVII.

ONE-HALF MILE SOUTHWEST OF H. & ST. JOE RAILWAY BRIDGE OVER EAST FORK.

		FT.	IN.
1.	Concealed		
2.	Shales, *olive, clayey*	2	6
3.	Limestone, *hard, blue*	2	6
4.	Shale, *black, fissile*	3	
5.	Coal (SUMMIT BED?)	1	
6.	Clay	3+	
	Total thickness	12	

The altitude of the coal is here about 760 ft. A. T.

As indicated, we correlate the coal of this section with the Summit bed, though somewhat doubtfully, as the facts seem equally to warrant its correlation with the Macon City bed. The distance, in a direct line, between the Eureka shaft and No. 46 (see pp. 14 to 16), is about one and three-quarters miles. The above section was taken at a point about midway between them. At the Eureka shaft the Summit coal occurs at about 772 ft. A. T., while at No. 46 it is 33 feet lower. If the descent be uniform, this would place the coal of the above bridge sec-

tion at about 756 feet, which seems sufficiently close to our figures to justify the correlation made.

At the road bridge over East fork, about three-quarters of a mile south of the Eureka shaft, the following section was measured:

Section XVIII.

AT MACON-COLLEGE MOUND BRIDGE (N. E. ¼ S. E. ¼ Sec. 19).

Altitude about 750 ft. A. T.

		FT.
1.	Concealed	
2.	Shales, *sandy, buff-colored*	3
3.	Limestone, *hard, blue, breaks with conchoidal fracture*	3
4.	Shale, *black, fissile*	4
5.	Coal (MACON CITY BED)	?
	Total thickness	10+

The coal has been drifted into here, but the opening has been abandoned. We correlate this coal with the Macon City bed, a better section of which is exposed along the banks of Patton creek, about a mile and a half southeast of this locality. The latter exposure is located just outside the limits of the sheet, but we insert the section here, since it represents the best exposure of these rocks observed.

Section XIX.

LOWER PATTON CREEK SECTION.

		FT.	IN.
1.	Concealed		
2.	Limestone, *hard, blue, usually in a single massive ledge; sometimes shows discontinuous lines of stratification*	3	
3.	Clay, *buff, varying to argillaceous shale*		6
4.	Shale, *black, fissile; contains nodular concretions from 10 to 20 inches in diameter; nodules frequently cross-fractured and spaces filled with calcite; a pyritiferous layer filled with fossils occurs at the base*	5	
5.	Coal (MACON CITY BED)	1	8
6.	Clay		
	Total thickness	10	2

Nos. 3 and 4 were observed to vary locally. The coal has been drifted into quite extensively all along the creek. About half a mile above, the limestone (No. 2) lies in the bed of the creek. Its surface is rough and nodular. Here the following section was taken:

Section XX.

Upper Patton Creek Section.

		FT.	IN.
1.	Concealed	2	
2.	Limestone, *hard, blue, in a single ledge*, exposed	1	
3.	Clay, *reddish*		6
4.	Black smut (Summit Coal-bed).		
5.	Clay, *more or less iron-stained, and variegated in light buff and yellow colors*	4	6
6.	Shale or clay, *blue, argillaceous; a 3-inch pyritiferous stratum, filled with fossil shells at base*	10	
7.	Limestone, *hard blue, nodular*, in creek bed.		
	Total thickness	18+	

The identity of limestone No. 2 of section XIX, and No. 7 of section XX, is shown by intervening exposures. It is noticebale that the difference of altitude between the two points is 20 feet, showing that amount of westward inclination.

A section, representing Nos. 19 and 20 combined, is given by G. C. Broadhead,[1] who visited this locality over thirty years ago.

We reproduce the section here, as it corroborates and supplements the above, besides bearing testimony to the accuracy of the work done by that indefatigable worker:

Section XXI.

Section on Patton Creek.

After Broadhead.

		FT.	IN.
1.	Limestone	1	6
2.	Shale, *bituminous*	1	3
3.	Coal, *observed at Fox's bank in section 33*	1	1
4.	Slope, *showing clays and shales from 6 to 10 feet*	8	
5.	Shale, *drab, inclining to olive; argillaceous*	5	
6.	Limestone, *bluish drab; weathering to brownish*	3	
7.	Shales or clay, *buff*		6
8.	Shales, *olive at top, dark blue at bottom*	1	1
9.	Shales, *bituminous, containing at the lower part a local bed of pyritiferous shales containing many fossils, viz.: Productus muricatus, P. æqui-costatus, Macrocheilus, Selenomya, Orbiculoidea, Chonetes Smithi, Teniopteris.*		
10.	Coal	1	10
11.	Fire-clay, *bluish.*		
	Total thickness	23	3

[1] Report of Geological Survey 1855-1871, p. 81.

There is a rise of the strata toward the south, bringing the Lower Coal Measures to the surface at Ardmore, with a corresponding elevation of the rocks under discussion. The limestone and shale above the Macon City coal is, therefore, frequently seen projecting from the higher slopes, and sometimes also the coal appears underneath as a black streak. At Ardmore the Macon City coal and overlying rocks appear at a stripping just below the air-shaft of No. 26. Farther south sections representing this coal were taken at several places east of East fork, most of which, however, lie outside the limits of the sheet.

Middle Fork Sections.—With the exception of the general sections at Bevier and Thomas Hill, no detailed sections of the Middle Coal Measures were obtained along Middle fork. The projecting ledges of limestone at numerous localities, however, give ample evidence of its presence. Toward the north they are much less conspicuous by reason of a heavy capping of drift and, doubtless, because they have been somewhat eroded. A southward dip carries the Lower Coal Measures below the level of the bottoms north of Thomas Hill, and the limestone of the Middle division is to be seen projecting from the slopes adjacent to the stream.

Chariton River Sections.—A few important sections were obtained in the limited area west of the Chariton. About two miles north of Hammack's mill the Macon City coal has been drifted into and stripped at several localities. It is here about 20 feet above the level of the bottoms. The following section was taken in this vicinity:

Section XXII.

TWO MILES NORTH OF HAMMACK'S MILL.

Altitude at base of section about 715 feet A. T.

		FT.	IN.
1.	Concealed		
2.	Sandy and clay shales		
3.	Concealed	4	
4.	Shale, *black, fissile*	3	
5.	Shale, *blue, argillaceous*	3	6
6.	Coal (MACON CITY BED), probably slid out of place	1	6
	Total thickness	12	

Interval to top of Lower Coal Measures about 5 feet.

A section evidently representing rocks not far above this horizon is given by Broadhead [1] from this vicinity, though we were unable to determine the locality. The coal No. 7 is probably the Summit bed:

Section XXIII.

NORTHWEST OF HAMMACK'S MILL—*Sec. 18, T. 57N., 16W.*

After Broadhead.

		FT.
1.	Limestone, *bluish gray*	1
2.	Shales, *sandy with brown and gray calcareous sandstone, slightly micaceous;* some beds *very hard, seem indurated*	12
3.	Limestone, *bluish drab, weathers to brown*	1
4.	Shales, *bituminous*	3
5.	Shales, *drab*	2
6.	Clay, *blue, and shales*	1
7.	Coal	1
8.	Slope with clay at bottom	9
9.	Limestone, *blue, concretionary below the clay*	
	Total thickness	30

According to the record of a shaft at New Cambria 2½ feet of coal, overlain by shale, appears at the horizon of the Macon City coal. A combined shaft and drill-hole at Lagonda, obtained by Mr. C. F. Marbut, furnished the following record:

Section XXIV (No. 8 of Section sheet).

LAGONDA SECTION (¼ *mile southwest of store*).

Altitude at top of section about 720 feet A. T. Interval to top of Middle Coal Measure about 150 feet.

		FT.	IN.
1.	Clay, *yellow above, blue and sandy below*	14	
2.	Limestone	3	
3.	Shale, *black, fissile*	5	6
4.	Coal (SUMMIT BED)	1	1
5.	Clay		6
6.	Shale, *bluish-white*	18	
7.	Limestone, *hard*	3	
8.	Shale and coal (MACON CITY BED)	4	
	Total thickness	49	1

Interval to top of Lower Coal Measures about 5 feet.

Owing to the imperfect results yielded by the drill, no distinction was made between the shale and coal of No. 8, but it is probable that nearly all of it was shale.

[1] Report Geological Survey 1855-1871, p. 79.

At the Fishtrap ferry, one and three-fourths miles south, and half a mile east of Lagonda, coal appears in the bank of the stream just above low-water mark. It is mined a little for local use.

Section XXV.

At Fishtrap Ferry near Lagonda.

Altitude of coal about 665 feet A. T.

		FT.	IN.
1.	Shale, *blue, argillaceous, becoming darker below*	6	
2.	Shale, *black, slightly fissile*	3	
3.	Coal	1	6
5.	Shale		6
6.	Coal	1	
	Total thickness	12	

Interval to top of Lower Coal Measures about 5 feet.

The thickness of the coal, as also the presence of the shale parting, is given on the authority of the owner, as high water covered the opening at the time of our visit. We correlate this with the Macon City coal. The presence here of a shale parting, as also the thickness of the overlying shale, is exceptional. As exposed, the bed shows more resemblance to the Bevier coal than to the higher seam. We are led to make the above correlation, however, from the evidence presented by the Lagonda shaft, where the Macon City coal is at about the same horizon. This is further corroborated by an outcrop of limestone, resembling the Macon City limestone, at the bridge over Puzzle creek, about three-quarters of a mile west of the ferry. The limestone crops out 5 to 10 feet above the horizon of the coal. Half a mile north of the bridge is another limestone outcrop, 25 feet above the last, which probably represents that overlying the Summit coal.

THE QUATERNARY GEOLOGY.

By J. E. Todd, Assistant Geologist.

The region covered by this sheet lies wholly within the great plain of the extra-morainic or marginal drift, which extends from northeastern Nebraska to southeastern Illinois. Its features and structure are quite simple. The main irregularities are the result of more recent erosion attendant upon its relation to the branches of the Chariton river. As it is near the divide between the tributaries of the Mississippi and Missouri rivers, wider areas of the original flat surface are found than further west. For the same reason, more of it lies at a high level.

The Topography.—The upland, which is at an altitude of about 850 feet, is quite even and level. Undulations of more than five feet are rare, and all undulations are very broad and gentle. As one goes toward the streams, in some places, the even surface very gradually declines, but more frequently there is a well-defined edge whence begins an abrupt descent. The former occurs most often when following an elongated promontory of the upland which projects between secondary valleys; the latter in other cases, especially when approaching the head of a ravine or valley. Sometimes a "flat," as we may call a separate flat area, may be found 50 or 60 feet below the upland level. These may not be classed, however, as terraces, because they seem to have no correspondence to each other; they seem rather the result of settling and sliding, than of original deposition. This supposition seems, moreover, to be borne out by their structure.

The Chariton river, with its branches, has cut valleys 125 to 175 feet deep in this plain. These valleys are bordered with low bluffs and, along the main stream, are sometimes over two miles wide. Traces of a terrace or "second bottom" are found lower down on the main stream, but have not been noticed in the region described. The "arborescent" arrangement of the valleys and probable erosion from a plain gently sloping to the south become quite evident from a study of the hypsometric map on page 6. It should be noted in this connection that but one shade indicates the surface between 700 and 800 feet.

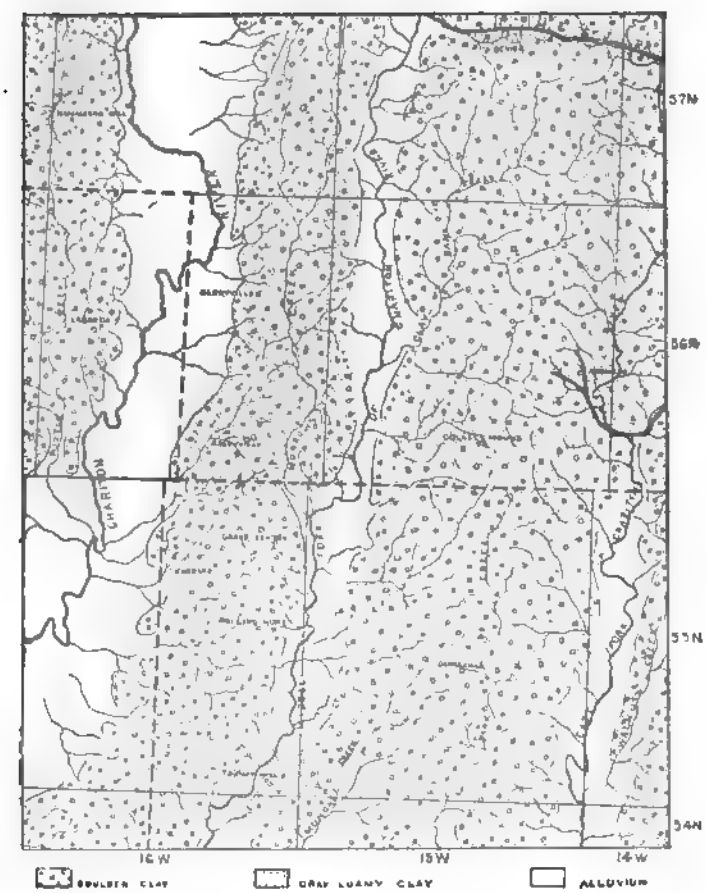

Fig. 4. Diagram showing distribution of Quaternary formations in the Bevier sheet.

In short, while the main topographic features are the work of simple erosion, the secondary are traceable to the sliding and creeping of the clayey deposits resulting from the attenuation of ridges, and the consequent effects of moisture and gravity.

The bed rock of the region, as is described on other pages, is of Coal Measure age, consisting largely of clays, shales, and marly limestones. Its surface seems to have been tolerably even, at least there were no prominent elevations. The earthy or superficial formations, which are probably all Quaternary, are, (1) the pre-glacial or basal clay, (2) the drift, boulder clay or till, and (3) the gray or loamy clay. This is their chronologic order. The distribution of these is shown in the opposite page plate.

1. *The Pre-glacial or Basal Clay.*—Under the drift clay, which is perhaps the most conspicuous formation of the region, there has been observed at several points a light gray clay, with a bluish tinge where it has not been long exposed. It is without northern pebbles; in fact may well be described as pebbleless. In color and texture it closely resembles the "gray loamy clay" (3). It is not very often seen. It is generally covered by the drift clay, and, when exposed, is apt to be mistaken for rearranged material of the gray loamy clay. For these reasons it seems not to have been, hitherto, recognized. Even now we could wish that its relations were more clearly established.

One of the clearest exposures was noted at the foot of the railroad grade west of Macon, in the ditch on the north side of the track. There, 8 to 10 feet of it are seen overlain by pebbly drift clay, 2 to 4 feet thick. The junction between, for a rod or two, is distinct, even and horizontal. It is about 25 feet higher than the top of Carboniferous shale exposed in an old quarry several rods northwestward. The base of the basal clay was nowhere observed, nor has it been seen very near exposures of bed-rock; but, from the facts stated above, it is estimated to be sometimes 25 feet thick. No fossils have been found in it. Less instructive exposures of this formation have been noted in similar relations east of Macon, west of Moberly and near Higbee.

It seems not improbable that "No. 3, Blue Clay, hard," of the Bevier section, No. II, given on the preceding page 15, and also Nos. 4 and 5, or at least the latter, of the "Black Diamond section," No. XI on p. 25, may be of this formation. Samples of these sections have not been directly examined.

2. *The Drift or Till.*—The next formation in order is an unstratified, pebbly clay, similar to that largely developed farther north. Its prevalent color is a yellowish brown, but the yellow is usually more decided in the upper portion and where it has been exposed. Lower down it is more of a reddish tinge, while below, especially where it has not been subject to infiltration of surface waters, it is of bluish drab or even of quite dark leaden hue. Moreover, although it cannot be definitely divided into different members, there is considerable difference in composition and texture between upper and lower portions. Above it is looser and usually more loamy, and there is a tendency to a stratified arrangement; below it is usually more clayey, more compact and more stony, especially near the base. It is generally divided by joints into irregular polygonal masses, hence is often popularly called "joint clay." Not infrequently these joints are occupied by carbonate of lime, sometimes in sheets which have been found ½ inch thick, and sometimes in irregular concretionary nodules. Sometimes the joints are blackened with oxide of iron. Along the upper boundary of the blue portions, that color is frequently found to obtain in the interior of the polygonal masses before mentioned, while the surface of the same is tinged buff next the joints.

The erratics scattered through the clay are mostly of crystalline rocks, granites, greenstones, and a red quartzite, evidently identical with the Sioux quartzite of southwestern Minnesota. These last seem not to be distributed much farther east than this area, though they are found as far south as southeastern Boone county, in considerable numbers. Limestone boulders are occasionally found, but they do not clearly belong to the local strata. In fact, we find few or no local boulders or pebbles in the drift clay except near its base. The erratics are frequently planed or striated, showing that they have come fresh from glacial agencies; they are quite evenly though rather sparsely distributed through the clay, yet boul-

ders seem generally more abundant near the base, less so at the top, and quite rare in the body of the formation. Pebbles are commonly less frequent and smaller toward the top.

This formation at higher levels commonly passes into the next above quite abruptly: *i. e.*, within a few inches, though not with a distinct line. This junction is usually quite horizontal, especially on the upland. At lower levels the junction between these formations is frequently curved and inclined, usually a little less so than the surface above.

The thickness of the drift or till, undiminished by erosion, has nowhere been directly observed. At New Cambria a cut exposes 30 to 35 feet of it. The cuts west of Macon indicate a thickness of about 30 feet. The sections of shafts on the preceding pages may possibly indicate a little greater depth, but the deposits mentioned have not been critically identified.

3. *The Gray Loamy Clay.*—This is the surface formation over all the region except on the lower portions of the more abrupt and longer slopes where the drift protrudes, and in the bottom of the valleys, where the alluvial deposits prevail. It is commonly of a light gray or whitish color. It is a plastic clay intimately mixed with fine sand and containing a few small well-worn pebbles, which are rarely half an inch in diameter. Small calcareous concretions sometimes occur in it, and much more frequently small black ferruginous shot-like nodules, ranging from half an inch down. It is not commonly jointed. This may be attributed to the intimate intermixture of fine silicious grains with the clay. It is quite impervious to water. This is attested by the frequent use of simple excavations for cisterns and reservoirs.

Commonly no distinct traces of stratification exist in it, but sometimes layers several inches in thickness and extending several rods are marked by the greater purity of the clay, which shows by its darker color and its checking in drying. Less frequently similar patches are found blackened by the occurrence of carbonaceous grains mingled with the clay. Where these cases have been observed, they have been several feet below the top of the formation, showing no clear trace of an old surface, and gradually passing on every side into the typical material of this formation.

The color of the formation is very uniformly a light gray, but occasionally it is blotched with yellowish spots, and quite rarely the whole is tinted a uniform yellowish, or buff color, like loess. It never, however, presents the vertical cleavage commonly seen in that formation, nor does it approach it in its porosity, nor does it yield as readily to corrasion. It resembles closely the "white clay" of Ohio, Indiana and southern Illinois, which has been recently studied by Mr. Leverett;[1] it is called by Mr. McGee in his "Notes on the Geology of Macon county,"[2] "Gumbo," or "upper portion of Lower Till." I have been unable, after visiting some of the localities described by him in Iowa, to see good reason for distinguishing between this formation and what he calls "Upper Till," which he correctly states, in part at least, passes laterally into loess.

Typical loess has not been observed in the area under consideration. It seems not improbable that the gray loamy clay is its geological equivalent, for the following reasons: (1) It corresponds in altitude. (2) It has a very similar relation to the till. (3) They seem to pass into one another not far from the Missouri and Mississippi. (4) From the nature of the case, it seems likely that a flood deposit should be finer and more clayey away from the main water-ways, and that, in consequence of the greater density resulting, iron compounds should be less oxidized, if not in fact less abundant. Whether this be the true explanation, or whether the silicious and more loamy character of the loess be traceable to its geographical relations to older deposits, has not been carefully weighed. In either case, however, it seems probable that this formation is the equivalent of the higher loess. This, I believe, is in harmony with the conclusions of the older Missouri geologists.

The maximum thickness of this formation is estimated not to exceed 25 feet. The deepest continuous exposure noted, near Macon, is less than 18 feet. As this formation is uppermost, and therefore much exposed, it has become much attenuated by erosion.

Illustrative Sections. — My colleague, Prof. C. H. Gordon, who is an experienced student of Quaternary deposits, as well as of the Carboniferous, upon which he is especially engaged,

[1] Am. Geologist, July, 1892.
[2] Trans. St. Louis Acad. Sci., Aug. 24, 1888.

has very kindly furnished me with some additional data which form an important supplement to my own observations. He reports from the shaft No. 46, K. & T. C. Co, on high ground near Bevier, the following section, which is No. 2 of the section sheet:

1.	Reddish yellow clay	20 feet
2.	Red clay, similar to No. 1, but harder	45 "
3.	Blue clay, hard	41 "
	Total of surface deposits	106 "

The Black Diamond shaft (No. 1 of section sheet), and three miles west of the above, gave the following; it is situated in a ravine:

1.	Black soil	2 feet
2.	Yellow clay	10 "
3.	Red joint clay	4 "
4.	Dark-blue clay, very hard	5 "
5.	Blue clay, softer	17 "
	Total surface deposits	38 "

A railroad cut, just east of Macon, is thus described by Prof. Broadhead: [1]

"No. 1. 6 inches, dark soil.

2. 1½ feet dark clay, with brownish stains. This may be the equivalent of the bluff.

3. 5 feet clay, slightly variegated, mottled brown with bluish drab, weathers to light yellowish brown, contains a few rounded pebbles.

4. 5 feet, somewhat like No. 3, but of deeper brown, more jointed, and weathers to a deeper color.

5. 12 feet brown jointed clay, dark stains on joints, is quite compact, contains many rounded pebbles, also white calcareous concretions; these concretions are sometimes found in flat perpendicular sheets like dykes, extending upward several feet, and of 2 inches thickness; pebbles are found adhering to them; the angle of excavation is about 45 degrees, and the action of frosts causes Nos. 3 and 4 to laminate parallel to the same."

The altitude of the cut is not given, and I am not sure that I have examined the same; but from a study of similar ones farther east, and especially of those just west of Macon, I do not hesitate to say that Nos. 2 and 3 correspond to what I have called gray loamy clay, No. 2 being simply stained with humus

[1] Mo. Geol. Rep. 1855-71, p. 76.

from the soil above; also, that Nos. 4 and 5 are equivalent to drift clay as defined above.

A combined section of the cuts on the grade west of Macon, extending about ¾ of a mile, is as follows:

Slope, about	8 feet
No. 1. Gray clay, with scattering small, round, white quartz pebbles	16 "
No. 2. Yellowish pebbly clay; pebbles mostly granite, greenstone and quartz, more numerous and larger than in No. 1. The top, not sharply defined, but changes in a foot or so, shows a nearly level line for several rods	30 "
No. 3. Yellowish gray clay, very few pebbles, none of them northern; resembles No. 1. Top sharply defined and level, extending for more than a rod, about	10 "
Undetermined to top of Coal Measure shales exposed north, about	12 "
Thickness of loose or Quaternary deposits	76 "

In evidence of the great thickness of the superficial formations between the Chariton river and Middle fork, Hon. S. L. Kasey informs us that the drill-hole on the ridge at the school-house, half a mile north of Kaseyville postoffice, penetrated 65 feet into clay without reaching the bottom, while in the drill-hole half a mile farther north, a depth of over 100 feet was reached, the upper 10 or 15 feet passing through yellow clay, while the lower 90 feet was in blue clay, containing fragments of wood at the bottom.

Alluvium.—The bottoms of the valleys of Chariton river, Middle fork and East fork present the usual features of flood-plains. The deposits left by these streams form fertile flats covering many square miles. While the ever-shifting streams have produced almost all possible combinations of the various constituents, loam, gravel and sand, and stiff clay usually of a brownish cast, though sometimes blue, the common arrangement, from top to base, is as follows:

1. Rich black loam, sometimes with less carbonaceous matter and more of clayey material from adjacent slopes.
2. Sand and gravel, irregularly stratified and mixed with clay.
3. Brownish or yellowish clay, hard and somewhat mixed with sand.

We may look upon the last as the accumulations resulting from sliding and creeping banks shaped and somewhat rearranged by the stream, the second as the work of the current, especially in freshets, and the first of the more quiet portions of the stream, with wash from the bluffs and ravines.

The depth of the alluvial deposits is estimated at from 15 to 20 feet along the larger streams. Prof. Gordon has noted that the alluvium not only covers the bottom of the valleys, but "along the Chariton, extends up the slopes to an altitude of 40 or 50 feet above the present flood-plain, and constitutes an important feature of the rich lands in that part of the State."

Economic Notes.—The alluvial lands form the richest and most lasting of the region. Moreover, they are the most easily tilled, excepting, perhaps, some that are imperfectly drained. Even these are mostly so high above adjacent streams as to be permanently drained with comparatively slight expense. Only persistent freshets are likely to inflict serious damage after such improvement.

The soils of the drift and gray clays do not very materially differ. Besides, on all slopes below the highest they are more or less intermingled. The middle and upper slopes, when not too steep, are reliable and fairly productive. The sub-soils furnish all ingredients desired in abundant supply. The lowest slopes are not only broken and cumbered with stone and shales in part, but are to some slight extent poisoned by mineral waters leaching from the latter. The upland flats, underlain by gray clay, though probably fairly supplied with proper mineral ingredients, suffer from troublesome physical difficulties. It is liable to drown in wet years and bake in dry. Mr. McGee, in his paper before referred to, well says: "The superior division gives origin to soil and sub-soil of peculiar tenacity and intractability, evidently by reason of the finely comminuted condition of its materials and the presence of a small percentage of unoxidized rock debris, and the consequent tendency to pack closely and undergo partial cementation. Unless carefully and judiciously tilled, the soil is prone to 'drown' in spring and 'bake' in summer, especially on the imperfectly drained plains forming the uplands; but these characteristics are lost in a measure along slopes where the natural drainage is superior and the sub-soil is leached to a considerable extent by more freely percolating waters."

STRUCTURAL GEOLOGY.

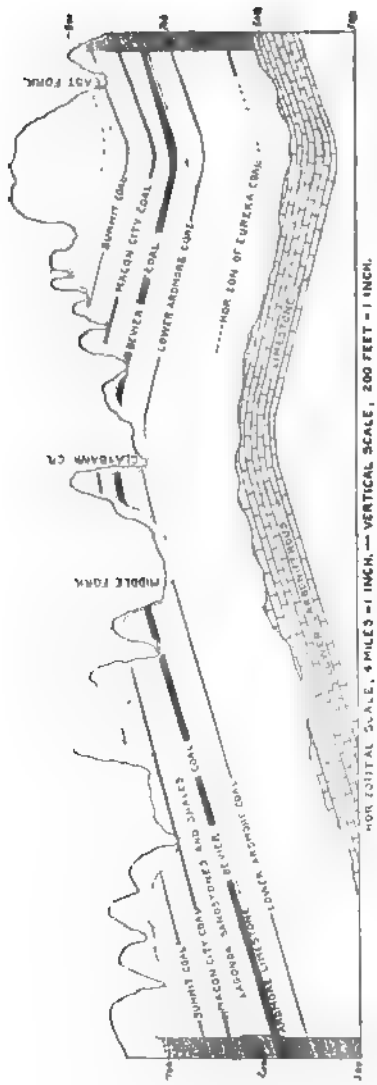

Fig 5 Diagramic cross section from northeast to southwest across the Bevier sheet illustrating the College Mound Anticline.

General Structure.—The structure of the region is extremely simple. The various strata all lie conformably upon each other, and within short distances seem to be practically horizontal. At greater distances, however, they are seen to have a noticeable dip to the southwest. Besides this general inclination, there are local undulations and variations that will appear in the study of the accompanying sections and map.

College Mound Anticline.—In addition to these local undulations above mentioned, a more general axis of elevation parallel with the strike enters the district southeast of College Mound and leaves it near the northwestern corner of the sheet. To the northeast of this line a considerable dip is manifest, as may be seen by a comparison of the sections of the Eureka shaft, on p. 14, and of No. 46, on p. 15. South of the latter the dip is reversed, bringing the Lower Coal Measures well up on the slopes; this is to be seen at Beecher creek (see p. 24), where the elevation of the Bevier coal is about 100 feet higher than at No. 46. The distance is about nine miles, showing a rise of

about 11 feet per mile. Beyond this the southwestward inclination is resumed to Thomas Hill, where he same seam is found 165 feet below its outcrop on Beecher creek, showing a descent of about 18 feet per mile.[1] This structural characteristic is well exhibited in the section, from northeast to southwest, of the preceding page.

The general westward inclination of the strata would carry the Lower Coal Measures below the Chariton river bottoms, and the reappearance of the Lagonda sandstones and shales there is to be attributed to the College Mound flexure.

A similar reversal of dip has been recognized by Broadhead in Linn county, joining Macon on the west, and is described as follows:[2] "Along the eastern line of the county the dip is northward from the Hannibal & St. Joe railway to New Boston, the depression amounting to 170 feet as referred to the stream. The true dip may be about 60 feet in that distance, or 5 feet per mile." As the fall of the river is only about 4 feet per mile, it is probable that the dip has been underestimated and should be considered nearer 10 feet per mile. South of the railroad a southward and westward dip is recognized, showing that an axis bearing northwest comes in somewhere in the vicinity of Bucklin. This is in a nearly direct line with the College Mound axis, and is doubtless an extension of the same fold. The outcrop of coal along the line of this fold in Macon county shows more or less irregularity, due probably to the disturbance attending its upheaval.

The sandstones and shales separating the Macon City and Bevier coals increase in thickness toward the west and southwest. This deposit, however, is subject to considerable variation both in character and thickness.

ECONOMIC GEOLOGY.

In the Bevier area, coal is the only mineral of great economic importance. In the eastern half of the district its production constitutes the leading industry, while the western half is given over almost entirely to agriculture. Building stones, clays and shales are of comparatively small importance as thus far determined.

[1] Owing to the small vertical scale used on the general section sheet, this structural characteristic is scarcely apparent.

[2] Report Geological Survey 1873-1874, p. 200.

COAL.

Five coal seams have been recognized within the Bevier area, four of which are coextensive with the limits of the sheet except as affected by erosion, as previously explained. All of these partake more or less of the undulations affecting the rocks of the region. Of these four seams, two only—the Bevier and Macon City beds—are susceptible of profitable working. The latter, however, is not of sufficient thickness to give it, at present, commercial importance in competition with the Bevier bed, which furnishes all of the coal now marketed from this district.

THE BEVIER BED.

The Bevier coal is by far the most important coal bed in the district, if not in the State, though it is not yet recognized as having so wide a geographic distribution as do some of the seams higher in the series. It is named from the town where it has been mined extensively for years, and which continues to be one of the chief coal mining towns of the State. This bed is also worked on an extensive scale at Ardmore, by the Kansas & Texas Coal Company. It is also mined for local use at various points within the area east of Middle fork. West of Middle fork we have no data upon which to base an opinion as to the presence and thickness of this bed, except that in a shaft put down in 1872, at New Cambria, just beyond the northwestern corner of the sheet, it is reported absent. A record of that shaft given from memory by Mr. John O. Jones shows 2½ feet of coal at about 196 feet from the surface, and 72 feet below this is another bed 12 inches thick, while 40 feet still lower a seam 4 inches thick on one side but thinning out at the other was encountered. The altitude at the top of the shaft is about 810 feet A. T. This shows the upper coal to be, doubtless, the same as that exposed in the slopes north of Hammack's mill, which we have correlated with the Macon City bed. (See p. 18.) Whether the bed 72 feet below this may be considered the equivalent of the Bevier, or whether the latter is absent or has been cut out here by a roll of the overlying sandstones and shales, we are unable to say from the data at hand.

The latter may be the true explanation, though the westward thickening of the Lagonda sandstones and shales might be considered an argument in favor of the former. At Lingo the bed, which is considered the equivalent of the Bevier coal, is found at 124 feet from the surface with 52 feet of shales and sandstones, but no coal, above. This would seem to indicate a like extensive deposit above the Bevier coal, with a rise, and the overlying strata removed by erosion previous to the deposit of the drift mantle, which is here 65 feet thick. The same deposit is 70 feet thick at New Cambria. A complete section of the New Cambria shaft would aid materially in the settlement of this question.

From what has been said it will appear that the presence or absence of coal in paying quantities in the portion of the sheet lying between Middle fork and Chariton rivers cannot be positively affirmed; we venture the opinion, however, that, in the lower two-thirds of this area, it may be looked for with some confidence. Concerning the region north of Kaseyville considerable uncertainty exists as to what extent the seam has suffered by elevation and erosion beneath the drift. (See p. 44.)

The sections of the preceding pages describe the most important exposures of this bed. Its limits in the eastern portion are clearly defined upon the map, and along this strip indications of its presence are numerous. The bed thins out east of the sheet, though its eastern limit has not been defined as yet. It is frequently diminished in thickness by "horsebacks," or rolls of the overlying sandstones and shales. In some cases the descent of the roof cuts out the coal entirely, but it is soon found setting in again farther on. In some places the sandstone furnishes a good roof, but, owing to its frequent transitions to a shaly character, it is more or less treacherous and requires considerable propping.

Detailed Sections.—The following sections will show the detailed character of the bed where studied:

Section XXVI (E of Section sheet).

DETAILED SECTION OF BEVIER COAL AT EUREKA SHAFT.

Altitude at base of coal about 724 feet, A. T. Distance from surface 75 feet.

		FT.	IN.
1.	Limestone, *hard, compact*	2	
2.	Shale, or clay, *drab*	4	

		FT.	IN.
3.	Coal	1	1
4.	Shale, *black*		1½
5.	Coal		10
6.	Clay, *drab*	1	

Total thickness of coal, 23 in.

Section XXVII (F of Section sheet).

DETAILED SECTION OF BEVIER COAL AT SHAFT NO. 42, K. & T. COAL CO.

(From measurements of A. Winslow.)

Altitude at base of coal about 727 ft. A. T. Distance from surface 118 ft.

		FT.	IN.
1.	Shale, *drab*	8	
2.	Shale, *white, sandy*	5	
3.	Coal, *hard, with thin pyrite films*	3	1
4.	Shale, *parting*		1½
5.	Coal	1	1
6.	Clay	1	4
7.	Sandstone	1	8
8.	Clay, *soft*.		

Total thickness of coal, 4 ft. 2 in.

The presence of a sandstone below the coal is exceptional, this being the only case in which it has been recognized at this horizon.

A sample of coal from this shaft was collected by Mr. Winslow from part of a freshly loaded market-car. The following are the results of analysis:

ANALYSIS OF BEVIER COAL SHAFT NO. 42, K. & T. COAL CO. AT BEVIER.

(Anal. No. 329, Mo Geol. Sur., J. D. Robertson Anal.)

	PER CENT.
Moisture	2.50
Volatile hydro-carbon and sulphur	39.15
Fixed carbon	48.67
Ash and sulphur	9.68
Total	100 00
Total sulphur	2.85

LABORATORY NOTES: The specimens of coal have a bright bituminous lustre with streaks of bitumen; they contain much calcite, little or no selenite, little pyrite, but much melanterite. The ash is of a dark, brick-red color. The coal coked in the porcelain crucible. but the coke was weak and almost lustreless.

These results show the coal to be high in ash, but moderate in moisture and sulphur contents. It is distinctly a bituminous coal, with a sufficiently high percentage of volatile matter to class it as a gas coal, if the illuminating power is sufficient, and were the sulphur contents lower. The percentage of sulphur is, however, as low as that of coals from Kansas which are used in Kansas City for the manufacture of gas. The results reached in the laboratory are adverse to the coal's being suitable for the manufacture of coke. A. W.

Section XXVIII (G of Section sheet).

DETAILED SECTION OF BEVIER BED AT DRIFT NO. 26, ARDMORE (Old Mayfield drift).

Altitude at base of coal about 755 feet A. T.

		FT.	IN.
1.	Shale, *sandy, more or less lithified in places*	20	
2.	Coal	4 to 5	
3.	Clay		1
4.	Limestone	3	

Total thickness of coal about 4½ feet.

The clay-seam was not recognized at No. 26 where this section was taken, but is reported as present elsewhere about Ardmore.[1]

A sample of coal from this drift was collected by Mr. Winslow from several mine cars, and yielded the following results on analysis:

ANALYSIS OF BEVIER COAL, DRIFT NO. 26, K. & T. COAL CO. AT ARDMORE.

(Anal. No. 332, Mo. Geol. Sur., J. D. Robertson, Anal.)

	PER CENT.
Moisture	1.72
Volatile hydro-carbon and sulphur	43.19
Fixed carbon	45.74
Ash and sulphur	9.35
Total	100.00
Total sulphur	4.35

LABORATORY NOTES: The specimens of coal have a bright lustre, but are somewhat shaly; contain much pyrite. The ash is of a dark brick-red color. The coal coked in the porcelain crucible, but the pores were small and the coke was weak and had a dull lustre.

[1]Near the mouth of the drift, and for two hundred feet in, the coal is capped by black, fissile, bituminous shale, 12 to 18 inches thick; but such is found nowhere else in the mine. A. W.

This analysis shows the coal to be low in moisture, neither low nor excessively high in sulphur, but high in ash. The remarks made above, concerning the value of the coal of shaft No. 42 at Bevier for gas production and coke manufacture, will apply equally well here, with the exception that the percentage of sulphur is somewhat excessive. A. W.

Section XXIX (H of Section sheet).

DETAILED SECTION OF BEVIER COAL AT COOLEY'S DRIFT (southeast corner of sheet).

Altitude at base of coal about 745 feet, A. T.

		FT.	IN.
1.	Concealed		
2.	Coal	3	
3.	Shale, parting		8
4.	Coal	1	

Total thickness of coal, 4 feet.

Section XXX (I of Section sheet).

DETAILED SECTION OF BEVIER COAL (three miles west of Darksville).

		FT.	IN.
1.	Shale, *arenaceous*	10	
2.	Coal	3	6
3.	Clay and shale parting	2	to 6
4.	Coal	1	6
5.	Clay		

Total thickness of coal, 5 feet.

Section XXXI (J of Section sheet).

DETAILED SECTION OF BEVIER COAL AT THOMAS HILL (Milman's shaft).

Altitude at base of coal about 635 feet, A. T.

		FT.	IN.
1.	Shale, *arenaceous*	23	6
2.	Shale, *black*		6
3.	Coal	2	6
4.	Dirt		6
5.	Coal	1	6
6.	Clay	1	6
7.	Limestone, *nodular*		

Total thickness of coal, 4 feet.

THE MACON CITY BED.

While the mining of this bed cannot at present be made profitable in competition with the thicker deposit below, nevertheless it may yield in the future a large amount of a good quality of coal. Near the western limits of Macon City it is operated to some extent by Fishbone and Link. It is here 22 inches thick and 70 feet from the surface; horse power is used for hoisting. It has been drifted on quite extensively along Patton creek, about one mile and a half south. At Eureka shaft it is 18 inches thick, which is about its normal thickness. At shaft No. 46., K. & T. Coal Co., however, it is two feet thick and it would probably pay to work were it not for the presence of the thicker bed below. Outcrops of the limestone above this coal are numerous along both sides of East fork, and coal is frequently found cropping out beneath the fissile shales underlying the limestones. At the north the exposures are adjacent to the channel, but recede somewhat as they rise in the hills toward the south. At Thomas Hill the limestone and shale appear a few feet below the river bottom, but the coal seems to be absent here. Above Thomas Hill, limestones appear on the slopes at various places, some of which may be at this horizon while others belong to that of the Summit coal. Sections XXIV and XXV show this coal west of the Chariton. That at Fishtrap is reported to have a clay seam parting six inches thick, though this has not been recognized elsewhere. This coal has also been worked locally north of Hammack's mill. The position of this coal on the map corresponds very nearly with the line separating the Lower from the Middle Coal Measures. (See detailed section B of Section sheet.)

THE EUREKA BED.[1]

The Eureka coal bed is encountered only at the Eureka shaft, west of Macon City, at a depth of 165 feet. The section measured here is as follows:

[1] From notes of Arthur Winslow.

This analysis shows the coal to be low in moisture, neither low nor excessively high in sulphur, but high in ash. The remarks made above, concerning the value of the coal of shaft No. 42 at Bevier for gas production and coke manufacture, will apply equally well here, with the exception that the percentage of sulphur is somewhat excessive. A. W.

Section XXIX (H of Section sheet).

DETAILED SECTION OF BEVIER COAL AT COOLEY'S DRIFT (southeast corner of sheet).

Altitude at base of coal about 745 feet, A. T.

		FT.	IN.
1.	Concealed		
2.	Coal	3	
3.	Shale, parting		8
4.	Coal	1	

Total thickness of coal, 4 feet.

Section XXX (I of Section sheet).

DETAILED SECTION OF BEVIER COAL (three miles west of Darksville).

		FT.	IN.
1.	Shale, *arenaceous*	10	
2.	Coal	3	6
3.	Clay and shale parting	2	to 6
4.	Coal	1	6
5.	Clay		

Total thickness of coal, 5 feet.

Section XXXI (J of Section sheet).

DETAILED SECTION OF BEVIER COAL AT THOMAS HILL (Milman's shaft).

Altitude at base of coal about 625 feet, A. T.

		FT.	IN.
1.	Shale, *arenaceous*	23	6
2.	Shale, *black*		6
3.	Coal	2	6
4.	Dirt		6
5.	Coal	1	6
6.	Clay	1	6
7.	Limestone, *nodular*		

Total thickness of coal, 4 feet.

THE MACON CITY BED.

While the mining of this bed cannot at present be made profitable in competition with the thicker deposit below, nevertheless it may yield in the future a large amount of a good quality of coal. Near the western limits of Macon City it is operated to some extent by Fishbone and Link. It is here 22 inches thick and 70 feet from the surface; horse power is used for hoisting. It has been drifted on quite extensively along Patton creek, about one mile and a half south. At Eureka shaft it is 18 inches thick, which is about its normal thickness. At shaft No. 46, K. & T. Coal Co., however, it is two feet thick and it would probably pay to work were it not for the presence of the thicker bed below. Outcrops of the limestone above this coal are numerous along both sides of East fork, and coal is frequently found cropping out beneath the fissile shales underlying the limestones. At the north the exposures are adjacent to the channel, but recede somewhat as they rise in the hills toward the south. At Thomas Hill the limestone and shale appear a few feet below the river bottom, but the coal seems to be absent here. Above Thomas Hill, limestones appear on the slopes at various places, some of which may be at this horizon while others belong to that of the Summit coal. Sections XXIV and XXV show this coal west of the Chariton. That at Fishtrap is reported to have a clay seam parting six inches thick, though this has not been recognized elsewhere. This coal has also been worked locally north of Hammack's mill. The position of this coal on the map corresponds very nearly with the line separating the Lower from the Middle Coal Measures. (See detailed section B of Section sheet.)

THE EUREKA BED.[1]

The Eureka coal bed is encountered only at the Eureka shaft, west of Macon City, at a depth of 165 feet. The section measured here is as follows:

[1] From notes of Arthur Winslow.

Section No. XXXII (A of Section sheet).

DETAILED SECTION OF EUREKA COAL, AT EUREKA SHAFT.

		FT.	IN.
1.	Shale, *argillaceous, black*	3	
2.	Coal	2	
3.	Clay parting, *drab*	6	6+
4.	Coal	2	

Total thickness of coal, 4 feet.

The lower bench is said to thin out and the upper to thicken in places. The clay parting varies in thickness from six inches to as much as five feet. Balls of pyrite in the coal impair its quality. The roof is poor and much water is encountered. A sample of the top bench of this coal was collected by the writer from several mine cars. It yielded the following results on analysis:

ANALYSIS OF EUREKA COAL, AT EUREKA SHAFT.

(Anal. No. 330, Mo. Geol. Sur., J. D. Robertson, Anal.)

	PER CENT.
Moisture	2.59
Volatile hydro-carbon and sulphur	39.30
Fixed carbon	41.11
Ash and sulphur	17.00
Total	100.00
Total sulphur	3 50

LABORATORY NOTES: The specimens of coal are streaked with bituminous layers; they contain pyrite and melanterite, also much calcite and considerable shale. The ash is of a dark, brick-red color. The coal cokes in the porcelain crucible, but the coke lacks coherence and is of a dull black color.

This analysis shows the coal to be low in moisture and moderate in sulphur contents; but the percentage of ash is excessively high. It is a decidedly bituminous coal and, with the exception that the larger quantity of ash impairs its value, the remarks made in connection with the analysis of the coal from Ardmore will apply here.

AVAILABLE COAL TONNAGE.

Bevier Coal. — In the northeastern and southwestern part of the sheet, this bed occupies a position below drainage level, while along the College Mound axis it lies well above this level, and, hence, has lost much by erosion. As shown on the map

its limits are quite clearly defined east of Middle fork, while some uncertainty exists as to its development west of that stream, as previously shown. The total area underlain by this coal is probably not far from 175 square miles. Allowing for its absence in the northwest, there would still remain at least 150 square miles. Reducing this still farther by 20% to allow for local thinning as well as for what has been mined already, we have not less than 120 square miles of workable coal in the district. The average thickness of the bed is a little less than 4 feet. The amount of marketable coal in a bed of coal 4 feet thick in an area of one square mile is considered to be about 3,200,000 tons.[1] Assuming the average thickness of the Bevier bed at 3½ feet, the total available tonnage within the limits of the sheet would be 336,000,000 tons, or over one hundred times as much as is now produced annually in the whole State.

Macon City Coal. — Excepting a comparatively small area in the western part of the sheet, this coal is principally above drainage level and, hence, has suffered much more by erosion than has the Bevier coal. Making a liberal allowance for this, there would still remain not less than 75 square miles underlain by this bed. Reducing this by one-third, however, as the bed seems to lack its full development toward the southwest, there remain 50 square miles, which, with 1½ feet thickness, will yield 60,000,000 tons of coal.

SUMMARY OF AVAILABLE COAL TONNAGE.

	Total possible area.	Assumed area.	Tonnage of assumed area.
Macon City bed	75 sq. m.	50 sq. m.	60,000,000
Bevier bed	150 "	120 "	336,000,000
Total	225 sq. m.	170 sq. m.	396.000,000

Altitudes of Coals.—The following table of altitudes is inserted here as a convenient aid in further exploitation. Some are based upon actual levelling, others upon aneroid readings; in addition, since the thickness of the strata intervening be-

[1] Preliminary Report on Coal, Mo. Geol. Survey — p. 49.

tween any two coal beds is subject to local variations, these results can be taken only as approximate. In the first column is given the elevation of the surface, so that the *depth* of any particular coal may be found by a simple process of subtraction:

APPROXIMATE TABLE OF ALTITUDES OF COALS IN THE BEVIER DISTRICT.

Locality.	Surface.	Horizon of Summit coal.	Horizon of Macon City coal.	Horizon of Bevier coal.	Horizon of Low Ardmore coal.	Horizon of Eureka coal.	Thickness of drift.
Eureka shaft	800	772	744	723	690	629	21
Bevier (station)	780	770[2]	745[3]	718	688	.....	40
Shaft No. 46	860	739	713	692	662[1]	.....	106
Ardmore (hill above store)	845	806[3]	781	756	725	.....	50[1]
College Mound	830	820[3]	795[3]	770	740	.....	50[1]
Darkville	826	790[3]	765	740	710	.....	50[1]
Thomas Hill (shaft)	675	682	660	624	594	.....	.....
Prairie Hill	725	685[1]	660[1]	610[1]	580[1]	.....	.....
Kaseyville	775	.....	755[4]	680[2]	685[3]	.....	100
Lagonda	750	696	671	620[1]	590	.....	40[1]
Ridge road near Hammack's mill	820	750	720	660[2]	630	.....	.....

[1] Probable [2] Doubtful [3] Probably eroded.

BUILDING STONES.

There are no quarries of special importance within the limits of the sheet. The limestones overlying the Macon City and Summit coals furnish extremely hard and durable stone, which is sometimes quarried for local use. It does not dress well, however, on account of its hardness. The sandstone found above the Bevier coal sometimes furnishes a stone suitable for light masonry, but it is generally too friable even for ordinary use. It has been quarried to some extent at Buster's quarry near Lagonda on the Chariton.

CLAYS AND SHALES.

By H. A. Wheeler, Assistant Geologist.

FIRE-CLAYS.[1]

At present no fire-clays are worked in the area comprised within the Bevier sheet, though several beds occur in the Coal Measures, one of which is at least likely to become of importance in the near future. These are found under the coal seams of the Lower Coal Measures which cover this area, and as one of these coal seams is usually of workable thickness, they are very favorably situated as regards cheap fuel for the kilns. The quality of the fire-clays thus far found is not favorable for refractory purposes, and even with washing they seem to be only adapted for coarse stoneware, for sewer pipe, paving brick and terra cotta, or the coarser applications of clay. These seams comprise:

The Bevier Fire-clay.—Underlying the Bevier, or, as it is usually known, the "four-foot" coal bed, is a thin layer of fire-clay that only averages 10 to 12 in. in thickness where exposed in the coal mines at Bevier, Macon City, Ardmore, Jacksonville and Thomas Hill. It varies from 8 inches to rarely as much as 3 feet in thickness, but the latter is only very local, and usually for only a few yards. It is usually of inferior quality from the presence of pyrite and calcareous concretions that occur in such large quantities as to make it unrefractory or fusible at furnace temperatures. On account of its thinness and poor quality, no occurrence of this seam, which is herewith designated as the Bevier fire-clay, is known in this area that would pay to work.

The Miller Fire-clay.—In drilling a hole on the Miller farm, 2½ miles south of Bevier, a seam of fire-clay is said to have been struck at a depth of 180 ft. from the surface with a reported thickness of 21 ft. It underlies an 18-in. coal seam, the lower Ardmore bed, that was found about 36 feet below the Bevier bed. Should further investigation verify this great and unusual thickness of fire-clay, it is destined to become of considerable importance, even if not of the best quality, as the

[1] The term "fire-clay" is used here in its popular acceptation, but it does not necessarily imply that the clay is highly refractory.

cheapness with which such a large seam can be worked would at least make it of probable value for sewer pipe and paving brick. It is possible, however, that the drill passes through soft or argillaceous shale, which might easily be mistaken for fire-clay by the driller.

Section XXXIII.

Record of the Miller Drill Hole.

About 2½ miles south of Bevier.

GLACIAL DRIFT.

		FT.	IN.
1.	Clay, *yellow*	63	
2.	Clay, *blue*	36	
	COAL MEASURES.		
3.	Limestone	2	6
4.	Sandstone	36	
5.	COAL (Bevier Bed)	4	6
6.	Fire-clay (Bevier Seam)	1	
7.	Limestone	3	
8.	Sandstone	7	
9.	Shale ("Pottery Seam")	20	
10.	Slate, *black*	5	
11.	COAL (Lower Ardmore Bed)	1	6
12.	Fire-clay.	21	
13.	Sandstone	2	
	Total	201	6

The Thomas Hill Fire-clay.—Outcropping on the steep hill-side, just below the hamlet of Thomas Hill, is a 5 to 6-ft. seam of fire-clay which is herewith designated as the Thomas Hill fire-clay. It crops out about 25 feet above the river, and is about 50 ft. above the Bevier coal bed, and lies immediately under the coal bed numbered (3) in section IV, of p. 17. As this Thomas Hill fire-clay seam has never been worked, the quality could only be determined from samples obtained by digging into the croppings on the hill-side. They show that it is a very fine-grained plastic clay of a light grey to blue color, and is stained yellow by iron. At the distance of a foot below the coal, the fire-clay has numerous crystals of gypsum in a yellow streak. If washed to free it from iron, gypsum, etc., it would probably make an excellent potter's clay, and possibly be good enough for refractory purposes; while the raw unwashed clay would make a good sewer pipe or paving brick. As Thomas

Hill is over 6 miles from the nearest railroad point, the fire-clay cannot be profitably worked or shipped with the present condition of the clay market.

This same fire-clay is found at shaft No. 40, of the K. & T. Coal company, two miles southeast of Bevier and is represented by No. 8 of section II given on p. 15. This shaft was unfortunately solidly cribbed when I visited it, so that it was not possible to obtain samples of this fire clay, which occurs here in workable thickness, and could be worked by the same shaft, plant and railroad switches that are used in moving the coal. This same fire-clay is likely to be found in other shafts that may be sunk in the high ground in the neighborhood of Bevier, and if found of good quality, may become of considerable importance. It will only be found over the highest areas, as the glacial erosion has been so severe here as to have planed it off in the valleys and lowlands.

The Eureka Fire-clay.— At the Eureka shaft it is said that they passed through a seam of fire-clay over 10 ft. thick, at a depth of about 100 ft. below the surface and 100 ft. above the Eureka bed.[1] As the shaft was solidly cribbed I was unable to get a sample of this thick fire-clay seam, so cannot say anything about the quality, or speak definitely as to its thickness. The fire-clay associated with the Eureka coal bed is occasionally quite thick at this mine, but it rapidly thins out to an unworkable thickness, as is indicated on p. 15.

SHALES.

Shales are very largely used in the manufacture of vitrified bricks, for which the various accessory ingredients that they usually contain make them eminently adapted; they are less frequently used for common brick, terra cotta, sewer pipe and drain tile, and occasionally they are found of sufficient purity to be suitable for refractory and pottery purposes. All shales, when ground fine enough, become more or less plastic, and are apt to weather into very plastic clays along the outcrop, hence they can generally be readily moulded into ware if their physical and chemical properties are favorable. There are several shale beds in the Bevier sheet area, and of these some six are found to be of workable thickness. Like all shale deposits,

[1] This must be either No. 8 or 14 of section 1, p. 14. A. W.

from the nature of their origin, these six workable beds vary greatly in their thickness, continuity and character, and not one of them is persistent over even the small area covered by the Bevier sheet. A shale bed 20 ft. in thickness is liable to thin out to 2 ft. or less in a distance of a few rods, and even be entirely replaced by a sandstone; while it may quite as suddenly vary from a very lean, sandy, hard shale to a very soft, fat, highly argillaceous shale in quite as short space, though such very sudden changes are unusual. But this fact should be borne in mind in prospecting for shales in this area, as the beds subsequently described are liable to vary greatly in thickness and continuity as well as in quality, and will need direct examination by test-pits or drill-holes to determine their value in tracing them out over unprospected areas. These workable beds are described in descending order, beginning with the uppermost bed found in this region.

The Macon City Shale—Outcropping along the edges of the valleys about Macon City, usually exposed along the banks of the streams, is a quite persistent bed of shale that varies from 5 to 15 ft. in thickness. This shale is above the Macon City coal bed that has been worked to a slight extent along the East fork bottom. About one mile east of Macon City this shale is about 5 ft. thick, as exposed in the bank of a small creek on the north side of the H. & St. J. railway, where it is capped by 5 ft of shaly limestone that is overlain by 3 to 10 ft. of glacial drift. The shale here is olive green, soft, fine-grained, fat and very plastic. Some of it was worked into brick by Mr. Foncher, of Macon City, and burned in his brick-kiln (clamp), but was found to shrink too heavily and to fuse at a common brick-burning heat. At Brown's brick-yard, ¾ mile west of Macon City, it shows at the foot of the hill, under a heavy deposit of yellow glacial clays, where test-pits and trenches have exposed about 12 feet; it is here rather soft, thinly bedded, but sandy to very sandy in texture and of a light gray color. About 2000 feet west of Brown's, and in the extreme northwestern corner of the map, it is exposed in the washed-out trench on the side of the Bevier and Macon road, at the base of the hill on the east side of Duck creek bottom, where it is 12 ft. thick; it is still quite sandy and coarse here, especially the lower por-

tion of the bed. A sample (No. 110 Wh.) from the upper 10 ft. of about 50 lbs. was taken along the trench, where it was well exposed and was tested with the following results:

PHYSICAL TEST OF MACON CITY SHALE.

Color, olive gray to yellow, heavily yellow to brown streaked with iron.
Texture, coarsely lamellar, coarse-grained, very sandy and soft, or H. 1.5 to 2.0.
Tastes lean and very sandy.
Slakes irregularly—a portion slowly and a portion rapidly into grains and flakes ¼ to $\frac{1}{10}$-inch in size, when dry and then immersed in water.
Pyrite is not noticeable, it having all oxidized and thereby so freely stained it yellow to brown.
Hydrochloric acid does not affect it except by dissolving out the iron.
When mixed with 19.2% water, after grinding to pass through a 20 mesh sieve, it makes a rather short, easily moulded paste, and bricklets from this paste, ranging in size from 4″ × 1″ × ½″ to 8″ × 4″ × 3″, dried rapidly in the air, and could be rapidly dried in a heated drying chamber without cracking. The shrinkage in air-drying was 4.5%, and the additional shrinkage on burning was 4.6%, or a total shrinkage of 9.1%. The shale burns to a good red color, suitable for common brick or terra cotta, and makes a fairly strong article when burned at 1800° F., or a cherry-red heat. Incipient vitrification occurs at 1850° F.; complete vitrification, or it becomes glassy (vitrified), at 1950° F., and it melts or becomes scoriaceous at 2100° F.

From these tests we conclude that this clay is well adapted for making common brick, terra cotta and drain tile. With care it can be used for paving brick, but there will be an unusually large loss from over and under burning,[1] while the strength will be somewhat deficient for this severe service.

This Macon shale bed again outcrops about 2000 ft. south of the above point, and 500 ft. north of the H. & St. Joe railway on the east side of Duck creek, where it rests on a ledge of limestone 12 to 16 in. thick that is quarried for a building stone. Here it is 10 to 12 ft. in thickness, but the lower 3 to 4 ft. is dark gray, very soft, fine-grained and plastic, while the upper 7 to 8 ft. is olive gray, coarse grained and lean or sandy, and intermixed with sandstone streaks ½ to 2 in. thick. By thoroughly mixing the lower fat portion with the upper lean portion, it would work better and make a stronger ware than the preceding sample. Both at this place and where exposed by the roadside the shale could be very favorably worked, as the stripping of yellow or glacial clay amounts to only 1 to 5 ft.,

1 From the fusing and incipient points being so near the vitrifying point, thus requiring exceptional care in firing a kiln.

and being on the flank of a side hill could be worked by open pits. The H. & St. Joe branch of the Burlington railway system, with its connections for eastern and western markets, is only 500 ft. distant from the latter and 2500 ft. from the former outcrop, with favorable country intervening for building a spur, while Macon City, with a population of 3400, is only a mile east, through which passes the Des Moines branch of the Wabash railway with its connections with northern and southern markets.

This same shale bed outcrops along the western edge of the bottom of the East fork of the Chariton river, about 2 miles west of Macon, at a point where the conditions are very favorable for open pit working; it has here about the same thickness and character as where sampled on the Bevier road, previously mentioned. This shale also outcrops at Coal hollow, about 2 miles southwest of Macon City, where it is 10 feet thick and favorably located for working and for railway connections.

Prospecting will find this shale bed to be of workable thickness anywhere about Macon City, but varying from very sandy to very fat in its texture. In the low valleys it can be found outcropping, or else by trenching down to it where covered by the yellow drift clay; but on the higher lands it can only be found by test pitting or boring. It outcrops again about two miles west of Jacksonville, where it is to be seen in the roadside gutter about 2000 ft. east, and about 40 ft. above the East fork of the Chariton river. Here it lies at the foot of gentle hills, with a cover of 3 to 8 ft. of yellow clay over it, and is favorably located for open pit working; it is about 12 ft. thick, of a very coarse sandy nature, and yellow in color. It again shows in the roadside at the crest of the hill by the old potteries, about three miles southwest of Jacksonville, where it crops out about 60 ft. above and about 1500 ft. east of East fork. Here it is over 8 ft. thick, of an olive gray to yellow color, soft, highly laminated and plastic. This Macon shale bed is liable to be found outcropping along the flanks of the hills of the East fork, Middle fork and Chariton rivers as well as along the branches and breaks that run back from these main drainage lines within the area covered by this Bevier sheet, though it may not always be of workable thickness (say 5 ft. or over) or of satisfactory quality.

The Thomas Hill Shales.—At Thomas Hill, on the east bank of the Middle fork of the Chariton river, there is a local and exceptional occurrence of three shale beds between the Bevier coal bed and the Summit bed, which are here 50 to 55 feet apart. The section on page 17 shows the relative positions and thickness of two of these beds at this place, which are Nos. 9 and 6 — 7 combined of the section. No. 9 bed is below the bed of the Middle fork, and is said to be 20 ft. thick where passed through by the whim shaft of Millman & Sons, on the bank of the river; on account of the shaft being cribbed this shale could not be examined. Nos. 6 — 7 crop out along the present bank of the river, and are covered at high stages of the water; together they reach 8 ft. or more in thickness, are brown colored and soft and plastic. The uppermost shale crops out about 10 feet above the river and immediately underlies the Thomas Hill fire-clay seam (see p. 58). It is 6 to 8 ft. thick, gray colored, soft, fat and plastic, and seems to be of excellent quality.

No. 9 of the Thomas Hill section is found at shaft No 48, of the K. & T. Coal company at Ardmore, where it is 5 ft. thick and occurs at a depth of 40 ft. below the surface and 2 feet above the Bevier coal; it is a soft gray shale at this point. Shale about this horizon is also found in some of the Bevier shafts, being 4 ft. thick in the No. 7 shaft of Loomis & Snively, one mile southwest of Bevier, at a depth of 24 ft., and Mr. Francis, the superintendent, says that he has found it to range from 2 to 8 ft. about Bevier. This would generally be too thin to permit of profitable working, as a sandstone 20 to 25 ft. thick occurs between it and the underlying Bevier coal bed, so that it could not be worked in conjunction with the coal.

The Pottery Shale Bed—At the site of the old potteries by the Penny bridge over the East fork of the Chariton river, about 3 miles southwest of Jacksonville, the following approximate section is to be seen along the roadside as it rises out of the river bottom to the adjoining high ground, which is 60 to 80 ft. above the river.

Section XXXIV.

Pottery Hill Outcrops.

Three miles southwest of Jacksonville, on the East fork.

			FT.	IN.
1.	Clay, *yellow*	1 to	5	
2.	Shale, *yellow* (Macon Seam)		8+	
3.	Limestone, *brown*	3	5	
4.	Slate, *black*		2	
5.	Coal (Macon City Bed)		1	3
6.	Fire-clay (Thomas Hill Seam)		1	
7.	Limestone	2	3	
8.	Shale *yellow to gray*	2	3	
9.	Sandstone	2	3	
10.	Coal (Bevier Bed)		3	
11.	Fire-clay		1	
12.	Limestone, *yellow and thin bedded*		4	
13.	Interval (shaly sandstone?)	10	12	
14.	Limestone, *yellow*		6	
15.	Interval (shale?)		5	
16.	Shale, *soft, and gray* ("Pottery Bed")		15	
17.	Slate, *black*		6+	
18.	Coal (Lower Ardmore Bed)		1	6(?)
19.	Fire-clay		?	

This "pottery" shale is of a light gray to olive color, thinly bedded, soft and plastic clay, which was formerly used by the two potteries that were located here for making stoneware. The weathered shale or clay is white to gray in color, very fine grained, very plastic and tough, but rather badly stained yellow by iron. It burns to a strong ware, but gives a black, spotted, pitted body, if the iron is not removed by washing. It would make an excellent sewer pipe, terra cotta or tile clay without washing. This same shale crops out on the western side of the river bottom, along the base of the hills, and was worked for the potteries on the Goddard farm, one mile west of the Penny bridge, also on Summers' farm, 2 miles southwest, at which places it has less iron than at Pottery Hill, so that the ware was less spotted (the clay was not washed). This shale is very favorable for mining at Pottery Hill, as it is 5 to 10 ft. above high water, and is covered by only 2 to 4 ft. of yellow clay stripping; but until more favorable shipping facilities are available, the bed can be of only local importance.

This same shale seems to underlie the Bevier coal at Bevier, if the Miller drill-hole (see p. 58) is reliable, as it was found in it

at a depth of 153 ft., or 21 ft. below the Bevier coal bed, where it had a thickness of 20 feet. If it should prove of as good quality as at Pottery Hill, this may become of great importance n the future, as with the good railroad facilities, cheap fuel and the probability of being able to work the shale from one of the already equipped mine shafts, all the primary conditions are favorable for the establishment of large sewer pipe and other coarse ware factories.

The Potteries.—The two potteries that were formerly operated at Pottery Hill made common stoneware, or salt and slip glazed jugs, crocks, milk-pans etc. The first one was built about 1870 by Louis W. Grotjohn, on the north side of the road, and just east of Penny bridge, at the foot of the hill; it was a hand shop and there were two small stone kilns. It subsequently changed hands a number of times, and was finally abandoned about 1885. The other pottery was started about the same time on the south side of the road, almost opposite the first one, by a Mr. Foncher, who ran a hand shop and had one kiln; this was also abandoned after running a few years. Both potteries used the weathered shale or clay from the Pottery bed, which was dug from the adjoining fields, or from the croppings one to two miles distant, on the west side of the river bottom, where it was found somewhat purer. They both did only a small local business, and in no case seem to have been managed by active pushing men, so that their final failure and abandonment was almost sure to follow from the keen competition of the large Illinois pottery centers. The kilns and buildings have been removed, so that to-day only the old broken and damaged ware remains to mark the site of this former industry.

THE BRICK CLAYS.

Almost the entire area of the Bevier sheet, excepting the river bottoms, is covered by the glacial drift, as previously described. In this region this glacial drift is mainly composed of tough, sticky, very fine-grained yellow and gray clays, that are occasionally slightly intermixed with gravel and sand. The gray and yellow clays are very irregularly intermixed, as is also the gravel, so that the deposit is very variable and uncertain in quality. This glacial clay is very poorly adapted for

making brick, as it is so "strong," or fine-grained and tough, that it is almost impossible to dry the bricks made from it in a reasonable time without their checking and cracking, even when salt is used. The presence of the gravel is also highly detrimental, though this fault is far less serious than the difficulty of drying without cracking. If sufficient care be taken to avoid draughts, the effects of the sun etc., and the bricks are left covered, even such a strong clay as this glacial clay can be successfully dried, but such extreme care involves a large amount of time, a very large stock on hand drying, excessive drying capacity and too much labor to permit of its being done in competition with clays that can be rapidly and cheaply dried without cracking; hence these glacial clays are not used. A reassorted or secondary loamy clay is used, however, in this district, that is found at the foot of the hills, and which results from the washing down of the glacial clays and the redeposition of coarser, more sandy portions at the foot of the slopes in the hollows and bottoms, which, on account of the presence of considerable sand and the washing away of the finest clay particles, makes a very fair brick clay. Such secondary deposits are thin, usually from 2 to 5 ft., depending on local conditions, and while found in sufficient quantities to suffice for the local building trade, the supply would not answer the demands of a large brick-yard without great danger of early exhaustion. At Foncher's, White's and Brown's small brick-yards at Macon City, producing 200,000 to 500,000 a year each, this clay is used exclusively, and the thickness is usually found to be from 2 to 3 ft. At Bevier, Loomis & Snively usually make 100,000 to 200,000 a year, in a temporary kiln, by hand, from this same secondary clay. This firm is the only maker of brick exactly within the area covered by the Bevier map, and they only attempt to supply the small local trade of Bevier.

THE GUMBO CLAYS.

The bottom land of the Chariton river, which averages 2 miles in width, the Middle fork bottom, which averages ½ mile in width, and the East fork bottom which averages about ½ mile in width, are quite generally covered with a very sticky, tough, dark to black "gumbo" clay that is well adapted for burning into the railway ballast that is now being so largely used by almost all the railways in the northern half of Missouri. This,

if hard burned, makes one of the cheapest and most satisfactory materials for ballasting road-beds. The gumbo of the Chariton bottom has already been made use of by the Davy Clay Ballast company (of Kenosha, Wisconsin), just east of the H. & St. J. railroad bridge over the Chariton river, near Callao, which lies just beyond the northwestern corner of the Bevier map. Here they burned one pit in 1892 that was about 2000 ft. long, for the Burlington railway sytem. While these Quaternary alluvial gumbo clays have thus far only been used for railroad ballast, it is quite likely that they will be quite extensively used in the near future for macadamizing county roads, for which purpose they are well adapted. While not so durable as good hard rock macadam, in regions like the Bevier area, where good rock material is scarce, the burned gumbo will make an excellent substitute if hard burned, while it can be prepared much more cheaply than rock macadam. Further details as to the manufacture of burnt ballast are deferred for the final report on the clays of the whole State, that is now being prepared by the State Geological Survey.

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BEVIER SHEET

92°30'
39°45

57 N.

CONVENTIONAL MARKS

	Geological Boundary	S.H.	School House
Hole	Horizon Line of the Bevier Coal	Sh.	Shale
rall Hole	Building	Ss.	Sandstone
	Ch. Church	Ls.	Limestone

Cal

GEOLOGICAL SURVEY OF MISSOURI.
ARTHUR WINSLOW, STATE GEOLOGIST.

SHEET REPORT No. 3.

A REPORT ON

THE IRON MOUNTAIN SHEET

INCLUDING PORTIONS OF

Iron, St. Francois and Madison Counties.

BY

ARTHUR WINSLOW, State Geologist.
ERASMUS HAWORTH, Assistant Geologist.
FRANK L. NASON, Assistant Geologist.

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ASSISTANTS.

H. A. WHEELER, assistant geologist.

Specialty: Clays.

C. F. MARBUT, assistant geologist.

Specialty: Detailed Mapping.

J. D. ROBERTSON, assistant geologist.

In charge of office.

T. B. MARBUT, assistant.

PREFACE.

Though effort has been made in the following report to equably distribute credit for work done, it is proper to emphasize and call further attention here to the share of some in this publication. Thus, the geological mapping of the sheet is largely due to Mr. Haworth, who spent several seasons diligently outlining the areas of the crystalline rocks in this and the adjacent country; his work at the same time defined the general limits of the Paleozoic clastics, thus restricting further work on these rocks to the study of the sections and other details. To Messrs. Lonsdale and Marbut is due almost entirely the credit for the topography represented on the sheet; for, although begun under the writer's immediate direction, the topographic mapping was soon left to their independent charge.

The idea prevailing in the other sheet reports of including exhaustive descriptive detail has had control here, and, thus, occurrences which have been noted in the Iron Ore report and other previous publications have been rediscribed, though mostly in new form and with valuable additions; this repetition of publication is unavoidable in preparing all area reports. In the present instance, we feel that no apology is necessary for presenting Mr. Nason's new and excellent descriptions of Iron mountain and Pilot knob; the deposits there are of world-wide reputation and are most instructive geological illustrations; we can have little fear of placing on record too much detail concerning these unique object lessons; on the contrary, it is our duty to gather and preserve, while we are able, all facts of value which the progress of mining may reveal, so that they may be used for the guidance and profit of those who come after us.

The geographic position of the sheet was determined through the assistance of the U. S. Coast and Geodetic survey. Two points were determined, one at Ironton, and the other at Potosi, and the following are the results of the final computations:

Ironton,	Lat. astronomical station	37° 36′ 30″.00
	Long. " " (W. of G.)	90° 37′ 40″.47
	Lat. of public school house cupola	37° 36′ 01″.22
	Long. " " " " (W. of G.)	90° 37″ 38″.61
Potosi,	Lat. astronomical station	37° 56′ 14″.59
	Long. " " (W. of G.)	90° 47′ 18″.86
	Lat. of court-house cupola	37° 56′ 13″.75
	Long. " " (W. of G.)	90° 47′ 18″.68

The station at Ironton was marked by a brick pier, and was located in a field about a hundred yards northeast of the railway depot. The pier at Potosi was of brick and stone and was located in the court-house grounds.

In addition to these points of control, the triangulation of the Mississippi River Commission was also used for properly adjusting the positions of the township and range lines.

In the proof-reading of this report, Mr. J. D. Robertson has given much assistance, and the accompanying index was prepared by him.

ARTHUR WINSLOW,
State Geologist.

JEFFERSON CITY MO., Jan. 8, 1894.

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View of the St Francois Mountains and the Arcadia Valley.

Looking northward from Arcadia.

REPORT ON THE IRON MOUNTAIN SHEET

BY
ARTHUR WINSLOW, STATE GEOLOGIST.
ERASMUS HAWORTH, ASSISTANT GEOLOGIST.
FRANK L. NASON, ASSISTANT GEOLOGIST.

INTRODUCTION.

By Arthur Winslow.

AREA AND LOCATION—RAILWAYS—TOWNS—INDUSTRIES.

AREA AND LOCATION.

The Iron Mountain sheet is named from the well-known Iron Mountain mine, situated in the northern portion of the area. It is a quadrilateral of 15′ extent in latitude and longitude, and embraces an area of 236.44 square miles. It is included between the lines 37° 30′ and 37° 45′ of north latitude and the lines 90° 30′ and 90° 45′ of longitude west of Greenwich. It covers portions of Iron, St. Francois and Madison counties. The location of the sheet with reference to county lines is shown in the following figure. It lies in the southeastern part of the State, being about 50 miles west of the Mississippi river, and less than 70 miles north of the Arkansas line.

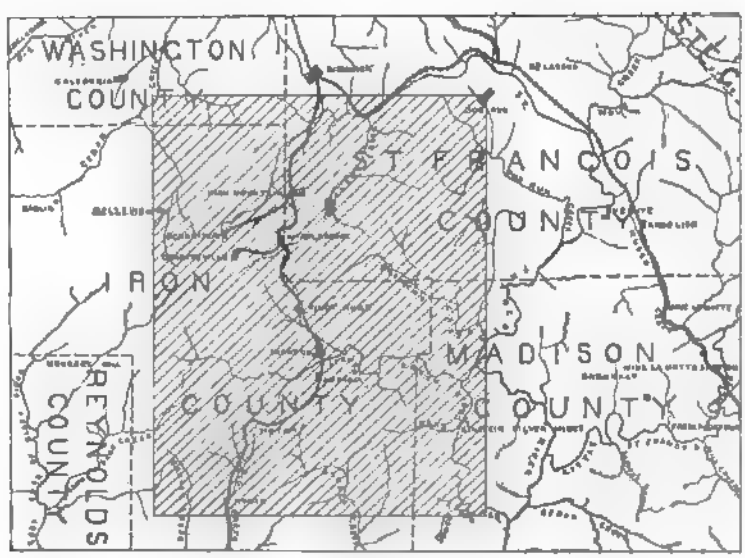

Fig. 1 —Outline map showing position of Iron Mountain sheet in Iron and adjacent counties.

RAILWAYS.

One railway traverses the sheet midway and lengthwise from the north to the south. This is the St. Louis, Iron Mountain and Southern railway, a division of the Missouri Pacific system. It is a single-track line, but heavily ironed and well ballasted. This is a line of heavy traffic between Texas and Arkansas and northern states, and large quantities of lumber, cattle, cotton and other farm products are shipped north.

Two short switches or spurs have been extended from Iron Mountain and Middlebrook, connecting with the quarries at Granitevllle.

TOWNS.

Three small towns and five small villages are situated within the sheet. These in the order of their population in 1890 as given by the eleventh census are as follows:

1. *Iron Mountain* (population 1101), on the Iron Mountain railway, is a mining town which has been maintained by the iron mines and dependent industries. The town was occupied almost exclusively by mine operatives. The number of these in past years was at times as much as 1000; this is now reduced to about 200, and hence the town is of much less importance.

2. *Ironton* (population 965), on the Iron Mountain railway, is the county seat of Iron county, and is a local trade center and point of distribution of commodities to the surrounding country. No special industry characterizes the place. It is provided with two flour mills and one wagon factory.

3. *Doe Run* (population 956), is located in the extreme northwestern corner of the sheet, at the terminus of the Mississippi River and Bonne Terre railway. It is a small town, which originated about five years ago, with the inception of lead-mining at that point. It consists of residences of miners and mill men and a few stores.

4. *Pilot Knob* (population 757), on the railway, about two miles northwest of Ironton, owes its existence chiefly to the iron mines and furnaces which were once actively operated here. It is essentially a town of residences. A few stores have been opened; but these are in part closed, with the abandonment of the mines.

5. *Graniteville* (population 721), about four miles southwest of Iron Mountain, has been built up by a large granite quarry industry which is maintained at that point. It consists chiefly of residences of

quarrymen. It is connected by a spur with the main railway line, but the nearest depot is at Middlebrook, nearly three miles distant.

6. *Arcadia* (population 408) closely adjoins Ironton and is practically a part of it, though under separate control. It has no special industry nor is it a place of commercial activity. It is chiefly distinguished as a summer resort; several pleasant summer residences have been built and a large number of visitors from St. Louis are attracted here each year. It is pleasantly located in the valley of Stout's creek, surrounded by porphyry hills.

7. *Middlebrook,* on the Iron Mountain railway, between Iron Mountain and Pilot Knob, is little more than a railway station. It contains in addition, a few residences, stores and a beer depot.

8. *Belleview,* located about six miles west of Iron Mountain, away from the railway, is a small country village, containing two or three stores and a postoffice.

INDUSTRIES.

The industries of the Iron Mountain sheet consist principally of agriculture, mining and quarrying. The principal farm products are corn and hay; wheat and oats are raised to a more limited extent. Iron ore is mined and shipped in large quantities from Iron Mountain; the same was true of Pilot Knob a few years ago, but work there is, at present, practically abandoned. Quarrying is actively prosecuted at Graniteville, and many car loads of stone are shipped yearly from this point to St. Louis. The mineral products will be discussed more fully under the head of economic geology, and further description will, therefore, not be made here.

In the southwestern corner of the sheet, the margin of the southwestern lumber region is included. One saw-mill is located near Hogan station, and shipments of lumber are made from there.

As indicative of the extent and comparative importance of the various industries, the following figures of commodities marketed in Iron county during the year ending June 30, 1892, extracted from tables compiled by Hon. W. C. Hall as State Labor Commissioner, are introduced here:

Stock (head)	3,180
Wheat (bushels)	1,866
Flour (barrels)	15,401
Granite, building, paving, spalls (cars)	1,093
Iron ores (tons [1])	5,076

[1] The production of iron ore at Iron Mountain for the same period is given by the State Mine Inspector as 78,960 tons.

PHYSIOGRAPHY.

By Arthur Winslow.

TOPOGRAPHY—HYDROGRAPHY—SOILS—FORESTRY.

TOPOGRAPHY.

The topography of the Iron Mountain sheet, as illustrated in the frontispiece, is of a hilly or semi-mountainous type. It is made up of low peaks and knobs or larger masses, between which are comparatively narrow and broken valleys. Though only 50 miles west of the Mississippi river, where the altitude of that stream is about 300 ft. A. T., the lowest contour on the sheet is 700 ft. A. T., and the highest contour is 1700 ft. A. T. while the general level of the valleys is about 1000 ft. A. T.

The distribution of the zones of altitude is well shown in the diagram opposite this page.

From these conditions it follows that the declivity of the streams is great and their flow rapid; corrasion along these streams is consequently active and base-levelling cannot be considered to have begun. The country is in a youthful stage of topographic development.

The influence of geology upon topography is here profound and everywhere discernible. The hills and mountains and the great mass of upland country, are mostly composed of Archean crystallines or of metamorphosed Algonkian rocks, while the surrounding and comparatively level valleys are composed of approximately horizontal Cambrian or Silurian strata.

The Mountains and Hills.—The features of relief of this sheet are members of what we term the St. Francois[1] mountains. No great central mountain mass is to be recognized here, however, of which the spurs and flanking ridges constitute the minor elevations. Neither have we a series of massive ridges or ranges as in the Appalachians

[1]The porphyry and granite mountains of southeastern Missouri have, up to the present time, been without a distinctive name. They have frequently been included under the term Ozark mountains. The Ozark mountains, as we define them, constitute the great plateau of Cambrian or Silurian rocks lying west of our area. It is a plateau in which the streams have cut deep, long and narrow valleys, separated by broad flat-topped divides or by long, narrow hog-back-like ridges. It is of post-Silurian age. The St. Francois mountains, on the contrary, are composed almost entirely of massive Archean rocks; they consist of many separate individuals, of varying size and shape, but approaching the dome or conical form as a rule; they are of pre-Silurian age. They differ thus, in material, structure and age from the Ozarks, and hence deserve a separate name. St. Francois (pronounced St. Fran-cis) is here applied as a name long associated with this region. It is the name of the county in which a large portion of these mountains occur, and is the name of the principal river traversing this region.

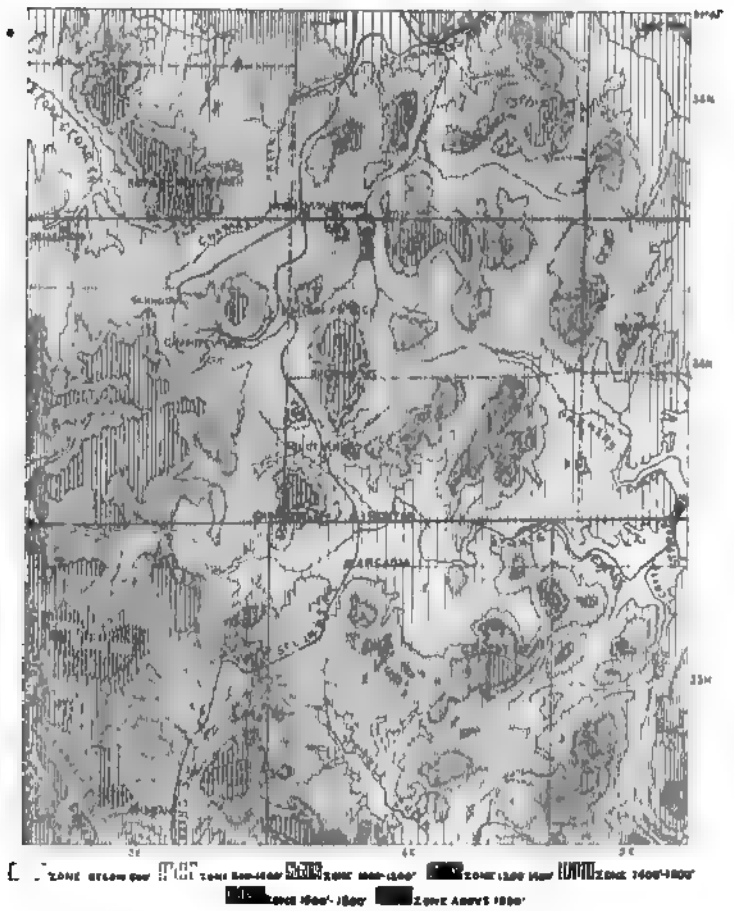

Fig. 2.--Hypsometric diagram of the Iron mountain sheet.

of the eastern part of the continent. The mountains are scattered promiscuously over the area—at times bunched into massive aggregates, elsewhere almost isolated. Viewed from the summit of one of the higher mountains, no prominent peaks are to be seen; the panorama is even monotonous, with its broad sweep of undulating forest-clad hills, of only slightly varying altitude.

The mountains are remnants of what must have been, in Archean times, a great land mass of volcanic rock, elevated well above sea level and subjected to erosion and corrasion. The development of the topography was probably begun at that early time, but was interrupted during the period of submergence attending the deposition of the Algonkian beds, to be vigorously renewed with the emergence of these beds above the waters. Probably after this event the greater part of the erosion took place, and the sculpturing of the hills and mountains which we now recognize was probably well-nigh completed before the Silurian epoch. Then this rugged country of granite and porphyry mountains was depressed and partially (possibly wholly) submerged in the Paleozoic seas, and the limestones and sandstones which now underlie the valleys were deposited over the lower portions and around the peaks and mountain masses, which remained above the water level as islands. A re-elevation later again brought the area entirely above the water level, and, since Silurian time, the limestones and sandstones have been subjected, probably, almost continuously to sub-areal erosion. As a consequence they have been in large part removed, the valleys have been deepened, the granite and porphyry hills are growing relatively higher; gradually the old pre-Silurian topography is being re-exhumed.

The mountain tops, we thus see, have been subjected to weathering influences, since Archean time, and the remainder of the country since the early Silurian. Hence great thicknesses of rock have been decomposed and the contours of the hills have been rounded. The profiles of the country are smooth and flowing ones, without jagged crests and sharp escarpments. In places the decayed rock covers the surface for a depth of 70 feet; elsewhere it has been eroded entirely and the bare rock is exposed.

Interesting phenomena resulting from sub-areal decay are to be seen at the Graniteville quarries. Here great ledges of solid granite are exposed on the hill-tops and sides, destitute of any covering.

Granite boulders of disintegration, known as "Elephant Rocks".

At Graniteville, Iron County.

Resting upon these ledges are massive boulders, of such imposing dimensions that they are known as "Elephant rocks." These, at one place, are arranged in a row along the crest of the ridge, and the group is aptly termed the procession of the elephants. The opposite plate, reproduced from a photograph, is of the leading members of this procession. Huge potatoes for a meal of the Titans they more resemble than anything else.

These great boulders are the wonder of all, and many are the conjectures as to their origin. Some great convulsion of nature seems to the uninitiated, at first thought, necessary to explain their existence. Yet, on careful examination, any intelligent person can recognize that it is the slow and quiet action of weathering that has produced the whole result. The larger masses and ledges of granite are seen to be traversed by frequent joint planes, or planes of fracture. Along these there is, at first, little or no opening separating the rock on each side, and this condition still maintains at present in some instances. Soon, however, water seeps in along these planes of fracture and, by degrees, decomposes and dissolves the faces of the rock; this action is supplemented by that of vegetable acids, by frost and by the general expansions and contractions caused by heat and cold. Thus an opening is gradually developed and, as this proceeds, the removal of the rock and further enlargement is hastened by flowing water. Thus, it is only a question of time until the blocks are separated by wide intervals, until the smaller blocks are completely disintegrated and the larger ones stand out as isolated "Elephant rocks." All stages of this process can be seen at these quarries. Fig. 1 of plate III illustrates the condition where it has proceeded only far enough to produce in a ledge a tesselated appearance. Fig. 2 of the same plate shows a still farther advanced stage; while the preceding plate II, opposite this page illustrates the final condition.

Similar evidences of decay are to be found at other localities; but so striking an example as this exists nowhere else in the State, and its superior would be difficult to find the world over.[1]

The principal mountains within this area are Buford mountain, 1700 feet high, Iron mountain, 1440 feet high, Stono mountain, 1600 feet high, Buzzard mountain, 1640 feet high, Shepherd mountain, 1600 feet high, and Taum Sauk mountain, 1800 feet high. These rear them-

[1]Through the recommendation of Prof. Wm. B. Potter, mining engineer of the company, the Iron Mountain company, which controls this land, has wisely reserved the portion covered by the boulders from quarry uses.

selves above the surrounding valleys to heights of 700 and 900 feet. Their outlines and dimensions are well shown upon the accompanying topographic map. Their structure and lithology will be described later.

A study of the map will show that these mountains, and other elevations of the area, are, in places, parts of large elevated masses of irregular outlines; that they are elsewhere detached but still irregular in shape, and that at times they are of the nature of isolated cones. The last condition has suggested the explanation that these mountains are remnants of volcanic cones and have always been isolated individuals. Other circumstances do not bear this out however. There is no evidence seen in any of concentric structure; no crater-like top can be recognized, no solidified core in the throat of such crater can be differentiated from the mass of the hill. On the other hand, erosion offers itself as all-sufficient to explain the phenomona. We have seen even from the meager evidence presented, that decay of these rocks has been very great. When we add to this the consideration of the vast time since their formation during which these rocks have been almost continually subjected to erosive action, we can realize how great must have been the decomposition, how enormous the mass of material removed. It is, therefore, in the highest degree improbable that such comparatively insignificant features as the present hills, if isolated from the beginning, should have withstood this long-continued action. We therefore feel compelled to admit, whatever the original surface configuration may have been, that it must by now have been obliterated, and therefore the most natural conclusion is that the existing features represent a stage in the general process of degradation by erosion. In the Taum Sauk mountain mass, in the southwestern corner of the sheet, we have one of the first stages, where the great mass of porphyry remains as yet undivided and is merely gashed by valleys. In Buford mountain and Buzzard mountain we have instances of a second stage, where large masses, of somewhat irregular form, have become detached from adjacent ones. In Pilot knob, the knob south of the Shut-In, east of Arcadia, and in the knob just east of Middlebrook, we have instances of a third stage, where such peaks are about to be isolated by corrasion of streams. Finally, in the case of Cedar hill, at Pilot knob, we have an instance of complete isolation.

FIG. 1.

FIG. 2.

Views illustrating the weathering of granite.

The Valleys.—The valleys, as already stated, are broken and comparatively narrow; they are not conspicuous features of the topography. The Belleview valley, west of Iron mountain, is the largest within our area, while the Arcadia valley is perhaps next in size and is more picturesque and pleasing. All of the larger valleys are, without exception, underlain by the stratified rocks of Paleozoic age. These rocks consist chiefly of magnesian limestones, but near the base of some sections are sandstones which crop out at points along the margins of these areas. A glance at the map will show that these valleys are not broad plains, traversed by meandering streams bordered by alluvial lands. On the contrary, they are of the nature of troughs sloping quite rapidly from the hillsides to the very channel of the streams. Further, they are diversified by hills of varying elevation, but, as a rule, of much less altitude than the surrounding porphyry mountains. These hills are generally thickly strewn with nodules and irregularly shaped fragments and masses of chert, whence they are known as "Flint hills." This chert, a residuary product from formerly superincumbent rocks, serves as a cap to protect these valley hills from erosion and rapid removal.

HYDROGRAPHY.

More than two-thirds of the area of our sheet is drained by the tributaries of the St. Francois river to the east. The river itself is represented in the northern portion and also by a small loop along the eastern border, due east of Ironton. Westward the drainage is into Black river, in Reynolds county. The stream of most considerable size within the sheet is Stout's creek, which flows east from Ironton into the St. Francois. This is, however, only about 15 miles long from source to mouth and drains an area of not more than 70 square miles.

The declivity of all the streams is great, and water flows off quickly. Owing to the steepness of the slopes adjacent to the drainage channels, rainfall is discharged rapidly, and the streams assume a torrential character on very short notice. The water subsides, however, within a brief time. During long dry spells the creek beds are almost entirely without water.

Corrasion is vigorous along all of the streams, and especially along those flowing to the east. Thus Stout's creek falls 200 feet between Ironton and its mouth, a distance of only eight miles. The streams are, therefore, still powerful agents of land sculpture. Their channels are generally well established; though, owing to the greater

eastward declivity, a gradual transfer of divides westward is doubtless in progress.

An interesting detail of drainage here is what is known as the Shut-In, on Stout's creek just east of Ironton. Plate IV, taken from a photograph here, illustrates the scene. The stream cuts directly across a narrow ridge of porphyry, notwithstanding the fact that the ridge terminates less than a mile south of the gap, and is there surrounded by limestone strata in which the creek channel could have been cut with one-tenth of the energy expended in excavating its present course. The feature has an antecedent appearance, antecedent in that a depression probably existed in the porphyry ridges when the limestone strata nearly or entirely covered it, and when the drainage system was first outlined. A synclinal arrangement of the jointage planes, shown in the illustration, favors this idea. Once established in such a gorge, a stream does not readily desert its channel. As corrasion along the main channel diminishes, however, it is probable that the stream will be diverted by the small tributary which now enters the creek from the south just below the Shut-In and that it will eventually be carried around the point of the ridge.

Throughout the mountainous portions of our area, in the massive crystalline rocks, springs are exceedingly rare or entirely absent. In the limestone valleys, however, they are quite abundant and contribute noticeably to the water supply.

SOILS.

The soils of the Iron mountain sheet are entirely residuary. That is, they are composed of the residues left after the decay of the country rock. Over the porphyry and granite areas much of the surface of the ground is covered by fragments of these rocks, derived from the disintegration of ledges, and here little or no soil can be recognized. Where soil exists over these crystalline rocks it is generally interspersed with fragments and is thin and clayey. The forest growth, though generally thick over such areas, is small and brushy. Grass grows throughout the woods, but the best of such land is poorly adapted to farming purposes.

The productive soils of this country are in the valleys over the limestones which lie between the porphyry and granite hills. Here most of the arable land is situated. These soils are also residuary, but the products of decay from the stratified limestone, shales and sand-

View of the Shut-In.

Two miles east of Arcadia.

stones yield a warmer, looser and richer earth than do those from the decay of the massive crystalline rocks.

Much of this valley land is, however, also illy adapted to cultivation, and this applies especially to the surfaces of the Flint hills. The ground there is so thickly strewn with chert nodules or boulders, that plowing is impracticable, and these nodules extend to undetermined depths beneath the surface. Part of the land in the depressions is also damaged by the presence of these indestructible residuary products. Further, owing to the existence of sandstone beds among the underlying rocks, as well as to the presence of a large proportion of silica in some of the limestones, the soils are frequently quite sandy. The shaly constituents, however, impart a loamy character.

The best farming lands of the sheet are in the Belleview valley, in the northwestern corner. In the Arcadia valley are also some good farms. None of the lands, however, are equal in fertility to those of the northwestern portion of the State, which are covered by a deep, rich, black soil.

FORESTRY.

By C. F. Marbut, Assistant.

The principal forest trees and shrubs occurring within the area covered by the Iron Mountain sheet are:

Sycamore ..... *Platanus occidentalis*
Slippery Elm ..... *Ulmus fulva*
American or White Elm ..... *U. Americana*
Wahoo or Winged Elm ..... *U. alata*
Sugar Maple ..... *Acer saccharinum*
White Maple ..... *A. dasycarpum*
Shellbark Hickory ..... *Carya alba*
Mocker Nut ..... *Carya tomentosa*
Bitter Nut ..... *C. amora* and probably *C. porcina*
Black Walnut ..... *Juglans nigra*
White walnut or Butternut (?) ..... *Juglans cinirea*
White Oak ..... *Quercus alba*
Post Oak ..... *Q. obtusiloba*
Pin Oak ..... *Q. palustris*
Burr Oak ..... *Q. macrocarpa*
Chestnut Oak ..... *Q. prinus*
Red Oak ..... *Q. rubra*
Laurel Oak ..... *Q. imbricaria*
Black Oak ..... *Q. coccina, var tinctora*
Black-jack ..... *Q. nigra*
White Ash ..... *Fraxinus americana*

Dogwood..... *Cornus atlenifolia*
Pawpaw..... *Asimina triloba*
Persimmon..... *Diospyros virginiana*
Cedar..... *Juniperus virginiana*
Common Locust..... *Robinia pseudacacia*
Mulberry..... *Morus rubra*
Black Gum..... *Nyssa multiflora*
Wild Cherry..... *Prunus serotina*, occurrence rare
Red Birch..... *Betula nigra*
Hackberry..... *Celtis occidentalis*
Red-bud..... *Cercis canadensis*
Common Yellow Pine..... *Pinus mites*
Buck-thorn..... *Rhamnus cathorticus*
Iron Wood or Hop Hornbeam..... *Ostrya virginica*
American Hornbeam..... *Carpinus americana*
Witch-hazel..... *Hamamelis virginica*
Hazel-nut..... *Corylus americana*
Black Haw..... *Viburnum prunifolium*
Buckeye..... *Æsculus glabra*

There are in addition to the above, several species of thorn and haw bushes and wild plum trees.

The whole area was, before settlement and the building of the iron furnaces at Iron Mountain and Pilot Knob, heavily timbered. During the time that these furnaces were in operation, the timber from the greater part of the area was cut off and converted into charcoal. Since the furnaces at the above places went out of blast, another growth of timber has sprung up and is now in a condition to grow rapidly. The first growth of bushes from the denuded land is always so thick that the progress is slow. In process of time some of the bushes gain advantage, and when once gained this advantage is held. As a result, the smaller bushes die out and the larger ones grow more rapidly. In the vicinity of Pilot Knob, where the first growth was taken off several years ago, the young forest is now composed of trees from 20 to 35 feet in height. This is the condition over all that part of the country from which the timber was first removed. Other parts have not yet passed from the bushy stage of growth. Along the extreme eastern portions of the area the timber has never been removed. The diagram on the opposite page shows the areas covered by these various growths.

The timber growing on the tops of the porphyry hills, where there is a soil of fair depth and moisture, is composed principally of red oak. There can, however, be no exact line drawn on one side of which we

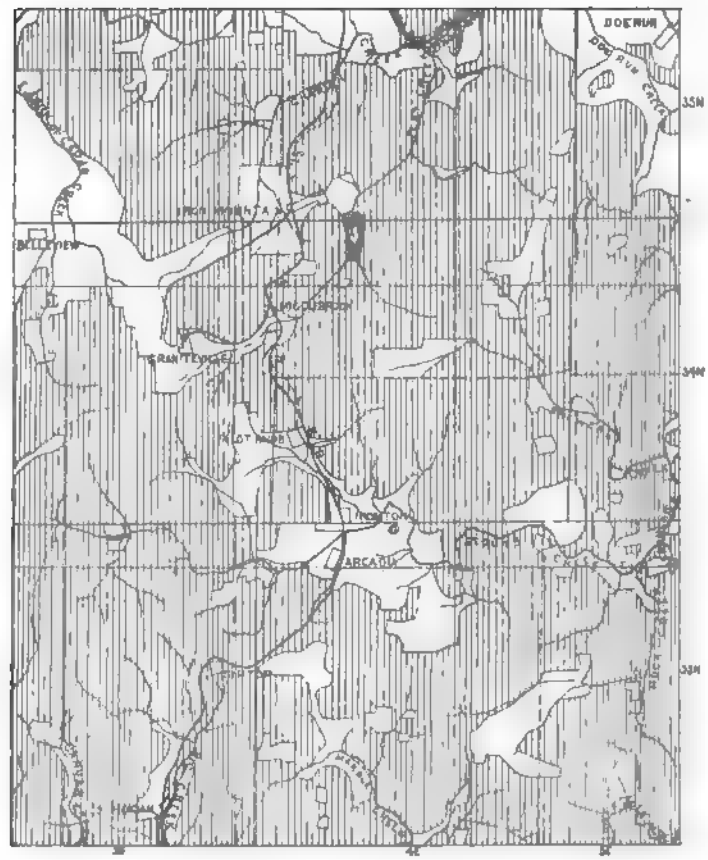

Fig. 5.--Diagram showing distribution of forest trees within the Iron Mountain Sheet.
Shaded portion is timbered.

can say one kind of timber grows and on the other side another kind, for the species have quite a wide range; but each kind of soil supports some one species in a more vigorous condition than the others. The red oaks grow in a moist and somewhat clayey soil, either rich or poor. In the hollows and along the hillsides, especially when there is a large amount of talus and the soil is rocky and consequently well drained, the growth is principally black oak. This tree is also the principal growth along the tops and other dry portions of the chert hills. White oak is found principally on the sides of the chert and porphyry hills, and in other moist, though not wet, clayey soils. The growth of the "Flat woods" is almost exclusively post oak. Along the eastern limits of the sheet, on the sides of the porphyry hills, especially where there is a remnant of the old coarse sandstone left, there is a scattered growth of pine. Cedar is confined to the areas underlain by limestone. Such areas occur both in the northeastern and in the northwestern quarters of the sheet, but the growth of cedar in the northeastern portion is very small. The growth of the laurel oak is not large; it is confined to the lowlands, such as the Arcadia valley and the valleys of the larger creeks, where there is a moist, compact, light or dark-colored soil. The bitter-nut hickory is confined to the neighborhood of the creeks and the shell-barks to the better class of soils, though it is not abundant anywhere. The other trees have a wide range. The growth of timber in the bottoms is composed principally of sycamore, elm, hickory and oak, sycamore being the most conspicuous. The oaks which grow along the creeks are principally pin oak and laurel oak. Walnut is not sufficiently abundant to be of any commercial value.

GEOLOGY.

THE ARCHEAN ROCKS—THE PALEOZOIC ROCKS—ECONOMIC GEOLOGY.

As has already been stated, the rocks of the Iron Mountain sheet consist of crystalline, massive Archean rocks, of crystalline stratified Algonkian rocks, and of clastic, stratified paleozoic limestones and sandstones. Beginning with the oldest, these will now be described in succession.

THE ARCHEAN ROCKS.

By Erasmus Haworth.

The Archean rocks of the area covered by the Iron Mountain sheet are eruptive or crystalline rocks, which may be conveniently divided into two general classes: (1) The Basic Eruptives, which occur in the form of dikes; and (2) the Acid Eruptives, including the granites and porphyries.

THE BASIC ERUPTIVES OR DIKE ROCKS.

The rocks of this class are found principally in the southeastern part of the sheet. They usually occur in well-marked dikes cutting through the granite and porphyries, or in boulders resulting from a partial surface decomposition of the same; but in a few cases they constitute bosses almost circular in outline. The dikes vary in width from less than half an inch to more than 150 feet. They usually trend northeast and southwest, or nearly so, but in some instances they vary widely from this. The walls are generally nearly vertical, and when otherwise, seem to be so irregular that no general law can be stated governing them.

On the map the locations of the dike rocks are shown. In many cases the limits of the dike itself could not be defined on account of the covering of soil and other products of decay. But in such cases numerous boulders are found lying on the surface.

Throughout the whole country the various dike rocks are remarkably similar, and differ so much from all other rocks to be found that they can be readily distinguished. They are dark in color, sometimes nearly black, but often shading into a dark green, while the other rocks are a light green, or some shade of red or brown. They are, when altered by decomposition, typical samples of what many geologists formerly called "green-stone." They are also much heavier than the ordinary granites or porphyries, and when in long thin fragments, will ring like metal if struck with a hammer.

Mineralogical Composition of Dike Rocks.—In the well-crystallized and unaltered specimens, the principal minerals of these rocks are the following: Triclinic feldspars, generally more than one, augite and olivine, with iron oxide and apatite as constant accessories, and brown mica as an occasional accessory. In those which are less perfectly crystallized there is always present a varying amount of unindividualized, or glassy matter, with the same minerals mentioned above; in such cases the feldspar crystals are small and slender, the augite crystals rarely well formed, and the olivine, in many cases, wholly wanting; but the oxide of iron is a constant accessory. If the rock is much weathered, the augite and often portions of the glass are changed into green, fibrous hornblende, which gives a green appearance to the rock. If the weathering is carried farther the feldspars are partially changed to kaolin, and here and there through the mass scales of white mica are observed.

Texture of Dike Rocks.—In texture these rocks vary from the holocrystalline, as coarse-grained as the ordinary granite, to a very compact glassy rock. In many of the smaller dikes, and occasionally in the larger, the microscope shows that more than half the volume of the rock is glass—the lava having cooled so rapidly that the particles of matter did not have opportunity to arrange themselves in crystals. Quite often certain mineral crystals, formed before the lava completely solidified, are scattered here and there through the rock, and producing what is known as the porphyritic texture. In other cases the texture of the rock is uniform throughout, and is quite coarsely crystallized

Descriptions of Dikes.—Thirteen different dikes are represented on the accompanying map, though the presence of some of them was judged of only by boulders lying on the surface; doubtless many more exist. In the following descriptions they will be taken up consecutively, beginning in the north.

1. At Iron Mountain, in a number of different places, mining operations have revealed dikes cutting through the porphyry. Some of these are less than 12 inches wide, while others are two or three times as large. On the west side of the hill such may be seen in contact with the overlying Paleozoic rocks, showing that they were formed prior to Paleozoic times. At the summit of the hill where the excavations are deepest, large masses of impure hornblende are found in contact with the ore. These probably represent dikes which have broken

through the porphyry, possibly at the time when the fissures originated in which the large ore veins were formed.

2. Along the main road leading from Pilot Knob to Farmington, about 50 yards south of Brewer's creek, in section 15, township 34 N., 4 E., boulders of dike rock were seen. The rock is quite fine-grained, is of a dark bluish-green color, is very tough and hard to break, and fragments of it ring like metal when struck with a hammer. In weathering, a very smooth surface is produced.

3. In section 24, township 34 N., 4 E., on land belonging to Mr. Elijah Smith, is a large dike, the rock of which, near the surface at least, is largely composed of long slender crystals of hornblende. Portions of this rock have also yielded green fibrous hornblende or uralite.

4. On the south side of a little porphyry hill in section 8, township 33 N., 4 E., are numerous boulders of dike rock, indicating the presence of a dike somewhat larger than the average. The rock is much coarser grained than the one last described, has a less greenish tint, and the boulders are roughened on weathering, due to the existence here and there through the rock of portions which resist decay better than the remainder of the rock.

5. In the southern part of section 3, township 33 N., 4 E., is an unusually steep, circular, porphyry hill which stands out alone in the valley. Adjacent to its southwestern side a narrow, sharp ridge extends to the southeast for nearly a fourth of a mile, which is so narrow and sharp that it has been named locally the "Hog-back." This ridge is a dike of a very fine-grained, glassy rock. The ridge owes its existence to the great resistance to erosion offered by the dike rock, the limestone on either side of it having yielded much more rapidly. The surface covering conceals the contact between the limestone and the dike, and thus their relative ages could not be absolutely determined, though there is little doubt but that the latter is the older.

6. Just south of Bowman's field, in the north half of section 6, township 33 N., 5 E., a few boulders of a dike rock were found which are of more than passing interest on account of their containing porphyritic quartz crystals. The quartz grains vary from microscopic dimensions to as much as an eighth of an inch in diameter. They are always greatly corroded, apparently as though after their formation they were partially redissolved, and as if solidification arrested the operation before it was finally completed.

7. On the north bank of Stout's creek, about half a mile above its mouth, just north of McAllum's field, near the center of the north half of section 4, township 33 N., 5 E., is a mass of dike-rock boulders, indicating the existence of a large dike beneath the surface. The boulders are large and sound, and yield fine specimens of olivine diabase.

8. Just south of the house formerly occupied by Mr. John Burk, in south half of section 4, township 33 N. 5 E., is a dike which can be seen cutting through the granite in the bed of a little branch. It is from three to four feet wide, and can be traced for about 20 feet. It trends northeast and southwest. The rock composing it is very fine-grained, black in color, and has a sub-conchoidal fracture. About two rods below this a second but much smaller dike crosses the branch in a direction parallel to the first. It is composed of essentially the same materials.

9. On the north bank of Rock creek, near Mr. Richard Payne's house, in section 17, township 33 N., 5 E., is a large dike, the exact width of which could not be determined on account of the covering of surface detrital material. Numerous large boulders are to be seen, and a little digging, done years ago, in time of an excitement about tin ore, showed that the solid dike was near at hand. At this place, also, small amounts of an inferior grade of asbestos were found in the surface clay. It has evidently some connection with the dike, but until found in place no prediction can be made regarding its extent. The rock at this place is quite coarse-grained, some of the slender feldspar crystals being a half inch or more in length.

10. Along the upper portions of a ravine running east, in the northeastern portion of section 20, township 33 N., 5 E., a dike may be seen traversing the porphyry. The rock is much lighter in color than the ordinary dike rock, and, judging from its mineralogical composition as revealed by the microscope, it is doubtless much less basic. It has a very fine texture, and macroscopically seems to be a homogeneous mass, but in reality has many minute feldspar crystals scattered through it.

11. On the northwest side of a high porphyry hill near the northeast corner of section 30, township 33 N., 5 E., numerous small dike-rock boulders were found. They were of the ordinary fine-grained kind and of no especial interest.

12. Along a small ravine running northeast, near the center of section 29, a dike is exposed in the porphyry. It has been strongly fractured, and each fissure has been filled with quartz. The fissures with their quartz veins pass into the porphyry, showing that they have been formed since the dike rock solidified. The rock itself is fine-grained, and possesses no qualities which would particularly distinguish it from other small dike rocks.

13. On a hillside half a mile west of Hogan, about a hundred yards north of the road, numerous boulders of dike rock cover the ground. They are olivine diabase, well crystallized, and are similar to that so extensively worked into paving blocks at Skrainka, in Madison county.

14. In a diamond drill hole in the limestone, just west of Shepherd mountain, the St. Louis Ore and Steel Co. at one time struck a dike rock at a depth of about 250 feet, approximately at the same depth at which porphyry was found in the other places near by. It is a beautiful steel-gray rock, composed principally of white feldspar and dark augite, the crystals of each mineral sometimes being one-half inch in length. When polished it is very handsome, and would make an unusually fine ornamental stone if it could be had in sufficient quantity and of proper dimensions.[1]

THE GRANITES.

The granites of this area are very important, both from a commercial and a scientific standpoint.

Mineralogical Composition of Granites.—The constituent minerals are principally quartz and feldspar, with the microscopic accessories, such as rutile hairs in the quartz and zircon crystals in the feldspar. The quartz is the ordinary variety, usually without distinct outline, but occasionally with a few partially-developed crystallographic faces. The feldspars include the two potash feldspars, orthoclase and microcline, and also oligoclase, with possibly small amounts of andesine. In a few places black mica occurs, but is never evenly disseminated; the segregations vary in size from that of a bird's egg to three or more feet in diameter, and are a great hindrance to the quarrying of the rock for such portions are of little value. Only in the rarest cases has hornblende been found, and then only as a few scattered crystals. In

[1] This dike is not represented on the map because it has no surface exposure.

weathered specimens the feldspars are sometimes decomposed, producing muscovite and epidote as secondary products.

Texture of the Granites.—The texture of the granites approaches the porphyritic. But few places have been seen in which the rock might not quite as well be called a granite porphyry. At some of the large quarries phenocrysts of feldspar may be found an inch or more long. In other places the texture becomes finer until the rock gradually changes into a porphyry.

It is very common for the feldspars to assume the role of a ground mass in which the quartz crystals are imbedded. In such cases the feldspar crystals are large, and have mutually interfered with each other in their formation, producing a granular structure through which smaller quartz crystals are scattered irregularly, precisely as they are scattered through the ground mass of a quartz porphyry. This is particularly well represented in the granites in the vicinity of Stono. Again, the quartz crystals are formed in spaces between the feldspars; here they occasionally have crystallographic faces, indicating that they were formed prior to the solidification of feldspathic material, or at other times they fill the irregular spaces between the feldspar crystals, as though they were formed last.

Distribution of the Granites.—The granites of this sheet are located in two distinct areas, with an occasional small patch here and there within the porphyry. These two main areas may be named the Graniteville area and the Stout's creek or St. Francois river area, because largely exposed along each of these streams.

The Graniteville area is by far the most widely known, on account of the extensive quarries in active operation. It occupies a strip of land about one-fourth of a mile wide and nearly a mile long, trending north and south. The whole is bounded by limestone, excepting the northern and northeastern portions, which connect with a small porphyry hill. The granite here is red in color, excepting such portions as are mottled by black mica. It is very coarse grained, and has many feldspar phenocrysts, some of which are nearly two inches in diameter.

A little less than a mile to the south of this area, but in the direction of its trend, is another small exposure of granite, generally known as the Pilot Knob company's quarry. The granite is almost indistinguishable from that at Graniteville. The rock is very coarsely grained

and decidedly porphyritic in texture. Many of the feldspar crystals. measure one and a half inches in length. The quartz grains are also very often well formed so that they may be called hypodiomorphic.

The Stout's creek area is very large, covering many square miles, and is joined on the east by an equally large area, extending beyond the limits of the sheet. Going eastward from Ironton, one finds it near the county line between Iron and St. Francois counties. As shown on the map, the boundary line between the granite on the east and the porphyry on the west is an irregularly curved line trending in a northwest and southeast course. To the south it reaches about a mile below the old silver mines on the St. Francois river, and to the north beyond Stono. It might well be expected that in so large an area the nature of the granite would vary greatly; but, with few exceptions, this is not the case. Along Stout's creek, and to a less extent on Brewer's creek, the rock is as free from porphyritic properties as any in the state. Here also the rock contains a small amount of black mica, uniformly distributed, and a few crystals of hornblende have been noted. In general appearance the granite is like that at the Milne and Gordon quarry at Syenite. But to the north of this, all the way to Stono, there is little or no variation; great masses of a dark pink or red granite, composed of quartz and feldspar, with here and there a slightly different texture, are everywhere encountered. As one approaches the western limit of the granite, on a high hill within the area, the texture becomes more allied to the porphyritic.

In addition to the two foregoing large areas there are the following smaller ones which are of considerable scientific interest:

1. On the southwestern side of the north hill at the Shut-In there is visible from the road a narrow strip of granite, red in color, composed entirely of quartz and feldspar, with a texture tending strongly toward the porphyritic. Several acres are covered by this rock. Sometimes the porphyry intervenes, cutting the granite areas into two or more sections, and it extends in this irregular way for more than a mile, the most western exposure being on the north part of the land belonging to Mr. Hutchins, in section 3. Each of these areas would furnish an excellent rock for paving blocks, and probably good dimension stone could be obtained.

2. Southeast from this place, in the southern part of section 2, township 33 N., 4 E., on a northwestern hillside, is another small area of about five acres, similar to the one just described. In general

appearance and fracture this rock is very much like a granite. A microscopic examination, however, showed that, in reality, it is a porphyry. It is composed of large feldspar crystals, which constitute more than half of the mass, with a fine-grained, ground mass filling the spaces between, composed of an intimate mixture of quartz and feldspar.

3. In the southern part of township 33 N., 3 E., are two small areas of granite which cover only a few acres. One is in section 27, about half mile west of Hogan, the other is in section 29. The granite here is composed of quartz and feldspar, with only an occasional trace of black mica, which, near the surface, is usually changed to chlorite. It is comparatively fine-grained, yet has the usual granite fracture, and in weathering produces the large, rounded boulders, so common on granite hillsides. Under the microscope it is seen to contain phenocrysts of feldspar imbedded in a coarsely crystalline ground mass composed of quartz and feldspar crystallized together, producing the granophyric micropegmatitic structure. In the exposure near Hogan the granite is a little finer grained than at the other place.

THE PORPHYRIES.[1]

The porphyries of the Iron Mountain sheet are abundant and varied. Their distribution can best be understood by a reference to the map. They occupy nearly one-half of the entire sheet.

In color they are usually some shade of red, or reddish-brown, often approaching a dull, rose-pink, and shading down into a dark, brownish terra cotta. Occasionally the various tints of red are wanting, being replaced by dark gray, which passes through steel gray into black.

Mineralogical Composition of Porphyries.—The porphyries are composed of quartz and feldspar, with iron oxide in small grains almost always scattered through the mass. The quartz is of the ordinary kind, and is often filled with gas bubbles, and not infrequently has numerous long, slender, hair-like inclusions of rutile. The feldspar is always either orthoclase (microcline), or one of the acid members of the triclinic series, albite oligoclase or andesine. So far as yet examined, there is no indication of a more basic feldspar ever occurring. It is very common to find two or more of the feldspars in the same mass, either with

[1] The name porphyry is here used to cover all the rocks, which from time to time have been have been designated by different authors by one or more of the following names: Quartz porphyry, feldspar porphyry, felsite, felsophyre, orthophyre, etc, It seems to be more appropriate than any one of the last names, especially since it has been so widely introduced in the country described that almost every citizen is not only familiar with the name, but can also recognize the rock.

or without the association of quartz. The few magnesian silicates are rarely found, and then only in minute crystals or grains. In some of the partially decomposed porphyries, epidote and occasionally calcite may be noticed, but they should be looked upon as secondary products.

Texture of the Porphyries.—The texture of the porphyries is comparatively uniform, but varies within narrow limits. The ground mass, or the main mass of the rock, is fine-grained, so that microscopically it appears to be a compact, homogeneous mass, but under the microscope it is usually seen to be holocrystalline, and only in the rarest cases can any glassy or uncrystallized matter be found. Scattered through this compact ground mass we usually find larger crystals of quartz, or feldspar, or both, ranging from microscopic dimensions to an eighth of an inch in diameter; but there is the greatest irregularity in their distribution; in some places they are wholly wanting, while perhaps 20 feet away they are quite abundant. These phenocrysts are always badly corroded, having been partially redissolved by the magma before it solidified.

In places these rocks exhibit the wavy lines or marks produced by the movement of the liquid lava before cooling, and made more apparent by slight inequalities in the constitution of the lava. Such phenomena, known as flowage structures, are represented in miniature by the flowage lines in the slags from our modern smelting furnaces. In the porphyries these lines curve around the included fragments and crystals, and they argue strongly in favor of the eruptive origin of these rocks.

The brecciation of the porphyry is very noticeable. Portions of Shepherd mountain, Pilot knob, Cedar hill, Buzzard mountain and of nearly all of the hills lying to the southeast of Pilot knob, possess this property in a marked degree. The fragments in the breccia are themselves composed of porphyry, which, in general, is the ordinary kind. They often have their angles fused or dissolved off, and in this way they merge into the mass of the porphyry around them. The microscope shows that there is no essential difference between the two, and that the fragments are visible principally because they chance to have a slightly different color.

Distribution of the Porphyries. — It is practically impossible to give geographic boundaries for each of the variations in color, composition and texture. Such a task would require an inordinate amount of detailed field work. All that will be attempted, therefore, in this

line is to mention a few places in which typical examples of the different kinds may be found.

Immediately west of Middlebrook is a dark gray porphyry consisting of a fine-grained ground mass filled with white triclinic feldspar crystals, which have a specific gravity of 2.665, indicating they are andesine. Along the road leading east from Iron Mountain, southeast of Wolf mountain, in section 3, township 34 N., 4 E., a very compact, fine-grained, almost black porphyry is exposed. No phenocrysts of any kind were noticed, though a thin section showed an included fragment.[1] Along the northern foot-hill of Anderson mountain, in section 21, township 34 N., 4 E., another unusually black porphyry may be seen. This also is fine-grained and very compact in appearance. Porphyries of a red color occur in the vicinity of Iron Mountain, Middlebrook, Pilot Knob, Ironton and many other places.

The brecciated porphyry is particularly abundant on Cedar hill, Buzzard mountain, and on almost all the porphyry hills to the southeast of Pilot knob for a distance of four or five miles. In a few places on the western side of Shepherd mountain the brecciated nature of the rock is very apparent, some fragments being fully two inches in diameter. In these fragments the flowage lines are also often well marked.

The porphyries bearing crystals of feldspar and quartz, may be found on almost every hill. The feldspar crystals are particularly abundant on Shepherd mountain, just west of Middlebrook, in many places on Taum Sauk mountain and on Grassy mountain.

RELATIONS OF GRANITE AND PORPHYRY.

Observations within the limits of this sheet and elswhere have revealed numerous instances of a gradual change in these rocks from the texture of a porphyry to that of a granite, and *vice versa*. The conclusion has therefore been reached that the granite and porphyries were formed from the same or similar molten magmas, and that their difference in texture is due principally to their solidifying under different physical condition, and secondarily to a slight lack of homogeneity in the magma. The unusually long boundary lines between the two rock masses in this area, and the numerous small isolated patches of granite already located make it possible to adduce many instances of gradation between the two rock masses, a few of the more important of which will be mentioned.

[1] See Bul. 5, Mo. Geol. Sur., p. 89, Fig. 4 B. The location given there is incorrect; it should be S W. quarter Sec. 3.

1. Near the boundary line between the granite and porphyry on the bank of Rock creek, in section 9, township 33 N., 5 E., a shaft was sunk years ago nearly 50 feet deep. A careful examination made of the walls showed that, though the rock at the surface is a distinct porphyry, as one descends the texture becomes coarse, somewhat irregularly, until at the depth of 20 feet it is that of an ordinary granite.

2. About two and a half miles to the northwest, along Stout's creek, similar conditions may be observed. In a number of places the rock in the bed of a stream is a granite, while the hill-top near by is a porphyry. In such cases the change is very gradual.

3. Still farther to the northwest, in section 24, township 34 N., 4 E., the contact line follows along on the east hillside. This is an unusually good place for observing the relations. Four or five different ledges are here exposed, one portion of each of which is granite and the other porphyry, with no indication of a break between them.

4. North of this last locality, from two to four miles, is a large hill called Buck mountain, which is entirely surrounded by granite. Approaching the hill from either the south or west sides, one notes that the quartz first becomes prominent as phenocrysts, and then that the texture of the ground mass changes so that parts of the hill may be called a porphyry, but nowhere is the change sufficiently rapid for a distance of 20 feet to witness much variation.

5. In the Graniteville area, and also at the Pilot Knob company's quarry near by, the porphyry and granite meet without any indication of difference in their origin. The transition is more rapid than in some of the places mentioned above, but it is sufficiently gradual to admit of the same explanation.

Other portions of America and different localities in Europe have furnished examples of one and the same magma assuming different textures in different places, due principally to a difference of physical conditions during solidification. But it is doubtful if an occurrence has yet been described which illustrates this condition so well, or on so large a scale, as do these here. There are literally hundreds of places where the phenomenon can be observed, with only here and there one in the whole Missouri Archean which bears evidence of the granite having been forced up through the porphyry.

THE ALGONKIAN ROCKS.

In addition to the foregoing description of crystalline rocks of Archean age, certain Algonkian conglomerates and slates are found which are to be described in this connection.

Of these rocks the most important and almost the only ones referable to the Algonkian are found on Pilot knob. On the summit of the hill is a cap of conglomerate and slates about 200 feet thick, which includes the ore bed. On the northeastern side of the hill the bedding structure is very perfect. The layers are about 12 inches thick, but many of these in turn are subdivided into much thinner layers. The most perfect stratification is comparatively close to the ore bed. Higher up it becomes much less noticeable. On the northwestern and western sides of the hill the stratification is not at all apparent; neither is it on the southern side. The gradual transition from the one structure into the other may be well observed by passing around the northern side of the hill. At tunnels Nos. 1 and 2 the massive nature is very pronounced, there being a score or more vertical joints to one which appears to be a seam produced by bedding. About the middle of the hill, on the northern side, the bedding seams begin to appear, and thence they increase in abundance to the northeastern and eastern sides, where they are dominant.

The rocks are mostly conglomeratic, but vary greatly in this respect. On the northeast, where the bedding is the most perfect, the included fragments are few. Passing westward and toward the summit, the fragments become very numerous; but when the west side of the hill is reached, in the rocks which have the most massive appearance, the fragments disappear entirely. The most perfectly bedded rocks, therefore, and those which are most massive, are freest from included fragments, while the intermediate grades, and especially those near the summit, are filled with them.

The matrix in all of those rocks is a fine felsitic mass mixed intimately with varying amounts of hematite. In places the ore forms almost the entire body of the rock, while in other portions the felsitic material greatly predominates.

The fragments of the conglomerate are principally porphyry. Occasionally pebbles of a light colored material are found which closely resemble chert. A large majority of such pebbles, however, upon close examination, proved to be porphyry fragments which have

been bleached by weathering to a light color. In addition to these there are numerous pellucid quartz crystals closely resembling the phenocrysts in quartz-porphyry. In size the fragments vary from more than twelve inches in diameter to microscopic dimensions. In shape the great majority are angular, looking as if they had just been broken from the solid rock; while others are partially rounded as though they had been somewhat water-worn.

The ore bed is located near the base of this series, and, in a general way, has a strike a little south of east, with a corresponding dip a little to west of south of about 13 degrees. But there is considerable variation in this. On the northeast and east the dip is to the southeast; on the west it is to the southwest. The angle of the dip is also quite variable. In the face of the long wall, exposed at the opening of tunnel No. 2, the ore bed can be traced for nearly a hundred feet, during which distance it drops about one foot in ten. Suddenly, however, it changes to an inclination of nearly 45 degrees, and the stratification becomes scarcely visible.

About a mile and a half south of Pilot Knob, on the south bank of Stout's creek, at the wagon bridge on the road between Ironton and Arcadia, the Paleozoic limestone has been worn away, exposing a little patch of conglomerate, less than two rods square, which also deserves mention. The matrix is entirely felsitic, and at numerous places has little pellucid quartz crystals strongly resembling phenocrysts in quartz porphyry. The included pebbles of porphyry vary in size from the microscopic, to three or four inches in diameter. Some of them are very angular, while others, especially the larger ones, are well rounded as though water-worn. The compact fresh matrix holds the fragments so snugly that when a mass is broken the fracture line passes through the fragments. It is difficult to say whether this exposure is or is not a member of the Pilot knob series. It is somewhat similar in composition and texture; but as there is no known connection, it is almost entirely gratuitous to call it a part of the same.

THE PALEOZOIC ROCKS.

By Arthur Winslow.

Distribution and Area.—The present area of the Paleozoic rocks within the Iron Mountain sheet is, in round numbers, 87 square miles. The original area was doubtless much greater. The marginal lines at present are anywhere between the 1000 ft. and 1600 ft. contours. It is probable that originally the sediments were at a uniform altitude, and reached or extended above the latter line. With the topography of this country, such a vertical extension means an expansion of the area covered, over nearly the entire sheet. The present variation in altitude of the marginal line is due almost entirely to the differences in the intensity of erosion at different localities. The details of areal distribution of these rocks are already shown on the accompanying map, and do not need further description here. Suffice it to repeat, that they are generally confined to the valleys between the granite and porphyry mountains.

LITHOLOGY AND MINERALOGY.

The rocks of this series include dolomites, magnesian limestones, marbles, chert, shales, sandstones, grits and conglomerates. The dolomites are by far the most abundant, and the sandstones are probably next in quantity.

The Magnesian Limestones.—The magnesian limestones are present in beds of great thickness. They are generally a coarse, crystalline dolomite of a pale, buffish color, though sometimes they have a compact texture and are of a pale gray color. In composition they are nearly a pure dolomite, with approximately the theoretical percentages of lime and magnesia, and with variable percentages of silica and iron. The following table of analyses, derived from various sources, will give a good idea of the composition of these rocks:

TABLE OF ANALYSES OF DOLOMITES AND MARBLE.

	1	2	3	4	5	6	7	8	9
Silica or insoluble residue...	5 11	3 85	2 06	17 88	6.97	5.30	3 93	2.96	4 67
Alumina	.....	.....	...	.....	1 11	not given	.....	.....	2 48
Ferric oxide	4 67	1 07	0 00	3.75			.....	.....	
Calcium carbonate	47.50	52 50	54.32	43.52	50 38	49 07	52 50	53 28	89.17
Magnesium carbonate.....	42 19	42 56	43 82	34.25	41 74	40 41	42 39	43 10	3.75
Phosphorus	.....	.....	.....	.....	.....	0 003	0 020	0 006	.....
Sulphur	.....	...	...	.....	.....	0.080	0.160	0.091	.....
Total..... ...	99 47	99.98	100 20	99.40	100.20	94 873	99 600	99.487	100 07

Nos. 1, 2, 3, are from Mace's quarry, section 8, township 33 N., 4 E. Analyzed by Mr. R. Chauvenet, Rept. Mo. Geol. Sur., 1872. Part I, pp. 6 and 7.

No. 4 is a pyritiferous limestone from the same locality, analyzed by Mr. R. Chauvenet. *Ibid*, p. 6.

No. 5 is a specimen from quarry northwest of Iron Mountain, used as flux at the furnace at that place. Analyzed by Dr. Litton. *Ibid*, p. 6.

No. 6 is an average sample of the last. Analyzed by Dr. Wendell of Troy, N. Y. *Ibid*, p. 7.

No. 7 is an average sample of the limestone from the quarry at Pilot Knob, also used as flux. Analyzed by Dr. Wendell. *Ibid*, p. 7.

No. 8 is a sample from Pilot Knob quarry, analyzed by Mr. J. T. Monell

No. 9 is a sample of marble from the Kramel land (section 2, township 22 N., 3 E.), by Mr. J. D. Robertson, laboratory of the Mo. Geol. Survey.

The silica in many of these limestones is plainly recognizable to the eye, and constitutes a considerable portion of the rock. Analysis 4, in the above table, indicates this, while one made by Mr. Robertson of a crystalline dolomite from a drill-core from near Graniteville, yielded 63 per cent of silica. It is a chemico-mechanically formed rock. Such mixtures of sandstone and limestone are very numerous, and it is difficult to know just where to draw the dividing line. The presence of a large amount of silica in the limestones affects the diamond drill very much as do some well-defined sandstones, and hence confusion often results in determinations made by the average drill-man.

Gradations from limestone into shale and grit also occur, especially along the contact of the beds with the Archean rocks, but these are not so numerous or confusing as are those between the limestone and sandstone.

The more crystalline varieties of the limestone are characteristically open and porous, being frequently filled with small vugs which are lined with fine dolomite crystals and often contain crystals of iron or copper pyrite. In the more crystalline varities large porphyritic crystals of calcite frequently occur, indicating an excess of lime. The denser limestones are less crystalline in structure, and the constituent particles are of sub-angular, almost rounded outlines, resembling those of a mechanically formed rock. Such limestones are also more frequently associated with quartz. Some of the limestones have a greenish tinge, due to a small percentage of chlorite.

The localities are numerous where limestones crop out, but those most favorable for observation are the quarries at Iron Mountain and Pilot Knob, the Belleview valley and the hill slopes immediately south of Arcadia.

The Marbles.—The marbles are crystalline limestones of the Paleozoic series. They are not coarsely crystalline, but very dense and finely crystalline. They are traversed by numerous seams of calcite. They are of gray and pink colors, and occur in beds ranging up to one foot in thickness. Some of these beds are very open or vesicular, the openings being filled with a bright red clay, and giving the rock a nodular appearance in section. These marbles are almost pure carbonate of lime, as analysis No. 9, of the preceding table, of a specimen from the Kramel land (Sec. 2, T. 22 N., 3 E.), shows.

The marked difference in composition between the marbles and the magnesian limestones of this region, may lead to an explanation of their origin. A discussion of this subject will not be attempted here, however. The only noteworthy localities in which marbles occur in the Iron Mountain sheet, is the one noted above, and another south of Arcadia, in section 19, township 22 N., 4 E., both of which are indicated on the map.[1]

The Cherts.—The cherts occur exclusively in blocks, nodules and fragments, scattered over the lower hills or buried in the surface soil or clay. Nowhere have strata of chert been observed in our area. Over all of the limestone valleys these nodules of chert are found. East of Ironton and west of Graniteville they are particularly abundant. They have a smooth, rounded outline, a sharp conchoidal fracture and frequently a more or less distinct concentric structure.

On the top of the low hill above the cemetery, just south of Middlebrook, are great masses of chert, as much as six feet in diameter. These are of angular outlines, and resemble porphyry blocks. The chert is here particularly dense, tough and devoid of structure. It is of a dull, pale gray, almost white color.

Along the road to Belleview from Graniteville, several "Flint hills" are crossed, which are abundantly covered by chert nodules.

The Shales.—Shales are not abundant nor important members of the series here. They are frequently found near the base of the column, near the contact between these rocks and the underlying porphyries. In such cases they are composed almost entirely of a fine, argillaceous, clay-like material, derived from the decomposition of the older rocks. Such clay shales are well represented along the ravines, and in the mine at Iron Mountain.

[1] A further description of these marbles, with especial reference to their industrial uses, will be found on a later page of this report, under the head of Economic Geology.

Elsewhere the shales are compact and laminated, and of the familiar, dark bluish gray color, strongly argillaceous. Such shales are found near the bottom of the drill-holes put down near Graniteville and Ironton. These are located on the map and will be described in detail later. Shales of an arenaceous character also occur; they are really sandstones of extremely fine texture, the constituent grains being as small as $\frac{1}{300}$ of an inch in diameter. Such shales are represented in the drill-holes above referred to, and also in others put down at Pilot Knob.

The Sandstones.—Sandstones, like the shales, generally occur near the base of the series, with no limestones beneath. But this is not always the case; for, in some sections, extensive beds of sandstone are represented underlain by thick beds of limestone. The rock is normally of a loose, friable texture, composed almost entirely of sub-angular grains of quartz, in which secondary enlargement of crystals is abundantly exhibited, the silicification not having proceeded far enough in most cases, however, to produce a quartzite. It is sometimes of a drab or white color, but is generally stained yellow. When in close contact with porphyry, it frequently contains particles of that rock which imparts a different color. Rock of the latter character is abundantly represented between the porphyry hills, just east of Iron Mountain. Other varieties of sandstone are exposed in mining excavations on the slopes of the mountain, and in quarries and road-cuts west and north of that place. In the Belleview valley, especially along Cedar creek, are many outcrops of sandstone. Between Middlebrook and Pilot Knob, west of the railway, is a sandstone quarry which has been worked for bridge piers; and west of Ironton, on the slope of Shepherd mountain is another.

Conglomerates.—The conglomerates are confined to the base of the series, at the contact with the underlying porphyry or granite. They are uniformly of the nature of a coarse pudding-stone, the boulders being well rounded. The latter may be either granite, porphyry or hematite, according to the nature of the contiguous rocks. They vary in size from pebbles up to boulders several feet in diameter. Those a foot or so in diameter are probably most common. Fine examples of such granite boulders are exhibited in the lower workings of the lead mine at Doe Run, where the ore is worked close along the contact. At the Iron Mountain mine, fine developments of hematite and porphyry boulders are exposed in portions of the excavations. The drillings at Pilot

Knob, at Ironton and at other points within the area, show the presence of porphyry boulders almost universally spread over the Archean floor. The matrix is generally a shale or clay from the decomposition of the crystalline rocks, or it may be largely limestone or sandstone, as is the case at Doe Run.

These conglomerates, generally of the less coarse varieties, are frequently exposed in road cuts and ditches, along the slopes of the Archean hills. Such are exhibited about Iron Mountain and also along the road to the Einstein mines, near the eastern border of the sheet.

MINERALOGY.

Few minerals, outside of the essential constituents of the various rocks, are associated with these strata. Galena is perhaps the most worthy of notice, by reason of its economic value. It occurs disseminated in the magnesian limestone at Doe Run in large quantities. It is also found in scattered crystals at other points. Small crystals of iron and copper pyrite are found in vugs in the limestones, as are also small dolomite and calcite crystals.

STRATIGRAPHY.

As an indication of the distribution of the various rocks just described, and as illustrating the detailed stratigraphy of the area, we will now proceed to describe a series of sections which have been obtained from various localities.

Doe Run and Vicinity.—At Doe Run a large number of the drill-holes have been sunk in prospecting the lands of the Doe Run Lead company. The results of all this drilling were kindly placed at the disposal of the writer by the superintendent, Mr. F. P. Graves. Most of these are, however, located beyond the sheet margin. They, together with the Doe Run mine, are both within the limits of the adjacent Mine La Motte sheet, and will be fully treated of in the report describing that area. Hence, only three from this locality are included here.

In the southeastern corner of the S. E. ¼ of the N. E. ¼ of section 17, township 44 N., 5 E., a diamond drill hole was put down, of which the following is a record:

Section I (No. 1 of Section sheet).

RECORD OF DRILL-HOLE No. 1 (on Merryman tract).

Altitude of top of drill-hole about 980 feet A. T.

		FT.
1.	Soil and clay	38
2.	Limestone, *yellow*	25
3.	Limestone, *gray*	63
4.	Limestone, *light gray*	9
5.	Limestone, *gray*	74
6.	Sandstone, *gray*	13
7.	Sandstone, *yellow*	25
8.	Limestone, *light gray*	5
9.	Limestone, *white*	16
10.	Limestone, *light gray*	1
11.	Limestone, *gray*	15
12.	Sandstone, *gray*	23
13.	Granite boulders	13
14.	Granite, *solid*	1
	Total thickness	321

According to other records obtained, two strata of sandstone are not always present in this vicinity, even when the section is of the requisite depth, and when it is extended to the granite. In some such cases the two sandstone beds are represented by one bed of greater thickness. Sandstone is even entirely absent in some holes which reach the granite, but in these cases the contact is on a hidden hill slope, above the horizon of the sandstone in section I. The conditions under which the sandstone occurs here are, therefore, somewhat as is illustrated in the following figure:

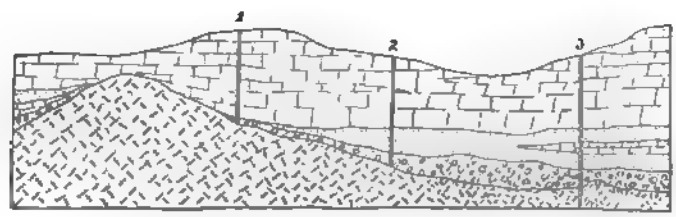

Fig. 4. Ideal cross-section at Doe Run, showing relations of sandstone and limestone beds.

Here, at 1, a drill-hole is sunk entirely through limestone to the granite, at 2 it passes through a single thick stratum of sandstone, and at 3, two strata of sandstone are encountered.

The sandstone in all the holes of this vicinity is generally at or near the bottom. Sometimes a thin stratum of limestone separates it from the granite, and almost invariably there is a body of granite boulders in a limestone matrix intervening.

The various colors of the limestone, indicated in the above section, are of little or no value for purposes of correlation; they are largely accidental characteristics, and indicate more the degree to which the rock has been acted upon by percolating waters than anything else.

In the valley, about two miles northwest of Doe Run, and about half a mile north of the sheet line, the following section was encountered in a diamond drill hole:

Section II (No. 2 of Section sheet).

RECORD OF DRILL-HOLE (Sec. 7, Twp. 35 N., 5 E.)

Altitude of surface perhaps about 980 feet A. T.

		FT.
1.	Soil and clay	7
2.	Limestone, *white and gray*	18
3.	Limestone, *green, some pyrite*	26
4.	Limestone, *gray*	1
5.	Sandstone, *white*	29
6.	Limestone, *white*	42
7.	Shale, *argillaceous, dark*	27
8.	Sandstone	7
9.	Sandstone, *soft, coarsely grained*	27
	Total thickness	184

The introduction of a large body of shale is especially noteworthy here, and attention is also to be called to the facts of the existence of two beds of sandstone, and of the prevalence of sandstone near the base of the section. These conditions are, however, not all constant, as is shown in the following diagram constructed from the notes of six different diamond drill holes, all put down within the same quarter section of section 7. Their proximity to each other is shown in the small diagram of the quarter section. No better illustration could be presented of the extreme variability of the rock column as previously referred to.

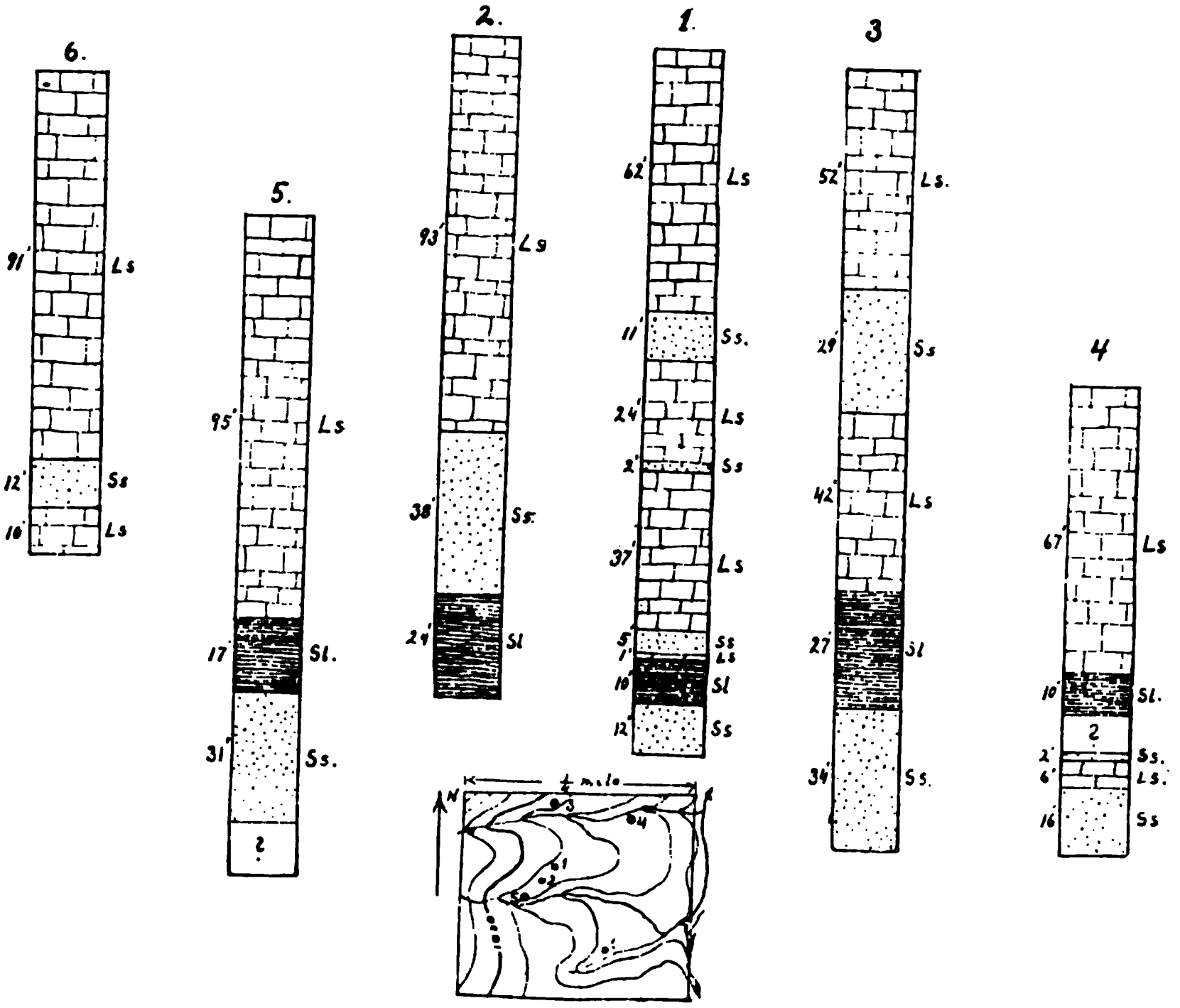

Fig 5.—Group of drill-hole sections near Doe Run, illustrating variability of stratification.

Other drilling done south of this, in section 18, revealed the same general conditions as are expressed in the following notes:

Section III (No. 3 of Section sheet).

NOTES OF DRILLING (Sec. 18, Twp. 35 N., 5 E.)

		FT.
1.	Limestone, *light colored* ..... at	34
2.	Limestone, *gray, gritty, like sandstone*	67
3.	Limestone, *gray, streaked with yellow rock*	78
4.	Shale, *white and soft, splits easily*	115
5.	Limestone, *white, harder than usual*	167
6.	Limestone, *darker and softer than last*	178
7.	Limestone, *gray, sandy and hard*	189
8.	Sandstone, *white, hard*	198
	Total thickness	198

The most important general conclusions to be derived from the study of these sections, are that the upper members are uniformly beds of magnesian limestone, of varying texture and color, while the lower members are generally sandstone, or arenaceous limestone; that beds of shale are sometimes found above these lower sandstone beds, and that beds of sandstone exist in places higher up in the section, between two limestone strata, that but such beds are not constant.

Proceeding westward from Doe Run, we pass over the great area of crystalline rocks included in Stono mountain and the surrounding country. Thence west of Stono postoffice in the valley along the turnpike to Iron Mountain, a coarse, friable sandstone is encountered at several places. It is the lower member and remnant of a series of sedimentary beds which once existed in estuary like-deposits between the surrounding hills. Such sandstone is exposed near the road about two miles west of Stono postoffice. It occurs on both sides of the road leading to Bismarck, between Pine mountain and the opposite spur of Stono mountain. It is well shown at the toll-gate at the northern end of Pine mountain, being exposed in ledges on both sides of the road. The rock here is very impure, coarse and gritty, being composed of grains of sand as much as one-tenth of an inch in diameter, and including pebbles of decomposed porphyry; much clayey material, resulting from the decomposition of porphyry, is also disseminated through the matrix of the rock, making it soft and friable. It is of a buffish yellow color.

Between Pine mountain and the northern extension of Iron mountain, similar sandstone crops out. At one place, at the forks of the road, about the middle of section 20, the rock is a decided conglomerate, consisting of small pebbles of sub-angular quartz, and of larger and more rounded porphyry fragments, cemented by a clayey matrix of decomposed porphyry. It is a soft, friable rock, and lies close upon the porphyry floor.

Iron Mountain and Vicinity.—Passing from thic to Iron Mountain, we have exposed in the excavations of the mine at that place beds of limestone and sandstone which taper to a feather edge up the mountain sides. These are well exposed in the cut on Little mountain, at the western end of the mine. The face here includes yellow, friable sandstone, 40 or 50 feet thick, overlying a bed of magnesian limestone, about 15 feet thick, which reposes directly upon the porphyry.

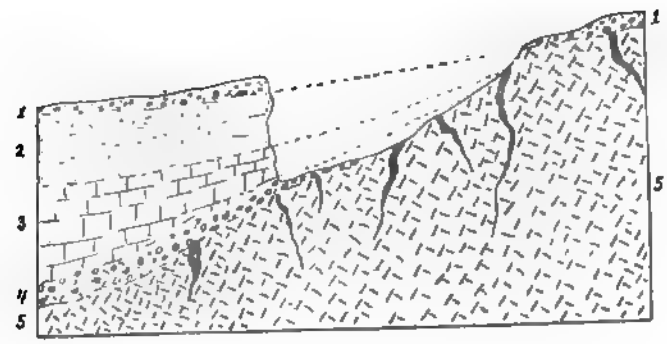

Fig 6 —Cross-section through Little mountain open cut at Iron mountain.

1. Surface clay and detrital ore.
2. Paleozoic sandstone.
3. Paleozoic dolomite.
4. Pre-Paleozoic clay and detrital ore.
5. Archean porphyry

The relations of the rocks here are well shown in the adjoining section.

The results of drilling about the mountain show, however, that this succession and relation of the rocks is not constant. Some ten or more churn drill holes have been put down in the valley along the foot of the mountain. The samples of the drillings are preserved by the Iron Mountain company, and were examined by the writer. The positions of these holes are exactly shown on the map of the mine accompanying the description of the iron ores, later in this report.

The following descriptions of the rocks encountered are from the writer's study of the samples, and from the records of the drilling prepared by Prof. Potter:

Section IV (No. 4 of Section sheet).

RECORD OF IRON MOUNTAIN DRILL-HOLE NO 17.

Altitude of surface is 1100 feet A. T.

		FT.	IN.
1.	Clay	15	
2.	Black mud	11	
3.	Limestone, *light gray, highly arenaceous, almost a sandstone*	34	
4.	Limestone, *brick-red, slightly arenaceous*	48	
5.	Sandstone, *grayish-red, coarse-grained, strongly effervescent*	9	
6.	Sandstone, *light pink color, very finely grained, calcareous*	67	
7.	Sandstone, *similar to 6, but coarser grained, non-calcareous*	12	
8.	Grit and *decomposed porphyry with pinkish gray, sub-angular and rounded grains of quartz*	48	
9.	Porphyry, *hard*		3
	Total thickness	244	3

Section V (No 5 of Section sheet).

RECORD OF IRON MOUNTAIN DRILL-HOLE No. 20.

Altitude of surface is 1103 feet A. T.

		FT.
1.	Clay	27
2.	Limestone, *light gray, strongly effervescent, little or no quartz*	38
3.	Sandstone, *calcareous very fine-grained*	22
4.	Opening or "cave"	19
5.	Grit and decomposed porphyry ("wash"), *brick-red, grains of quartz and limestone, effervescent*	29
6.	Decomposed porphyry	164
	Total thickness	294

Section VI (No. 6 of Section sheet).

RECORD OF IRON MOUNTAIN DRILL-HOLE.

Altitude of surface is 1101 feet A. T.

		FT.
1.	Clay	20
2.	"Clay rock," *light yellow, strongly effervescent, arenaceous*	5
3.	Limestone, *dull gray, fine-grained, arenaceous, effervescent.*	12
4.	Limestone, *gray, somewhat arenaceous, effervescent, fine-grained*	14
5.	Limestone, *white or light gray, coarse-grained, crystalline, dolomitic, little or no quartz*	16
6.	Grit and decomposed porphyry, *brick-red, calcareous, with quartz*	28
7.	Decomposed porphyry, ("wash")	57
	Total thickness	152

Section VII (No. 7 of Section sheet).

RECORD OF IRON MOUNTAIN DRILL-HOLE No. 21.

Altitude of surface is 1103 ft. A. T.

		FT.
1.	Clay	18
2.	Limestone, *yellowish gray, strongly effervescent, silica in very fine particles*	42
3.	Opening ("cave")	12
4.	Limestone, *reddish-gray, strongly effervescent, gritty and ferruginous*	7
5.	Porphyry ("wash"), *decomposed, brick-red, strongly effervescent.*	27
6.	Porphyry, *decomposed*	33
7.	Porphyry, *hard, light brown, somewhat effervescent*	1
	Total thickness	140

Section VIII (No 8 of Section sheet).

RECORD OF IRON MOUNTAIN DRILL-HOLE NO. 22.

Altitude of surface is 1065 feet A. T.

		FT.
1.	Clay	17
2.	Sandstone, *light yellow, coarse-grained, non-calcareous or very slightly so*	28
3.	Sandstone, *pale yellowish-gray, finer grained, grains round to sub-angular, non-calcareous.*	32
4.	Limestone, *gray, fine-grained, slightly effervescent, arenaceous*	57
5.	Limestone, *light drab or gray, very feebly effervescent, a good deal of quartz in very fine particles; more of a fine siliceous shale than a limestone.*	49
6.	Porphyry ("wash"), *decomposed, pink, effervescent, arenaceous*	45
	Total thickness	228

Section IX (No. 9 of Section sheet).

RECORD OF IRON MOUNTAIN DRILL-HOLE NO. 15.

Altitude of surface is 1059 feeet A. T.

		FT.
1.	Clay	12
2.	Limestone, *yellow, gray and pink, effervescent, little or no quartz*	28
3.	Sandstone, *fine-grained, pinkish and gray, effervescent*	70
4.	Sandstone, *gritty, coarse, quartz grains somewhat angular, effervescent*	39
5.	Sandstone, *finer grained, gray, very slightly calcareous*	29
6.	Sandstone and grit *of quartz grains and porphyry fragments, non-calcareous*	46
7.	Sandstone, *gritty, decomposed porphyry and quartz, strongly calcareous*	13
8.	Porphyry, *decomposed, with ptnkish clay, porphyry fragments and quartz, iron ore in lower part, highly calcareous*	110
9.	Porphyry red clay	13
10.	Porphyry, *hard, with iron ore*	7
	Total thickness	367

Section X (No. 10 of Section sheet)

RECORD OF IRON MOUNTAIN DRILL-HOLE NO. 12.

Altitude of surface is 1060 feet A. T.

		FT.
1.	Clay	13
2.	Sandstone, *pinkish-yellow, sub-angular quartz particles of medium size, cemented in part with iron oxide; some grains of porphyry; slightly calcareous*	81
3.	Limestone, *gray, magnesian, but strongly efferescent; large amount of quartz present*	20
4.	Sandstone and limestone; samples at various depths are as follows:	
	At 126 ft., *sandstone, finer grained than (2), pinkish, strongly calcareous.*	
	" 153 ft., *a coarse grit composed of grains of quartz discolored red, green and yellow; also grains of porphyry.*	
	" 173 ft., *limestone and sand, gray, with quartz; powder effervescent.*	
	" 230 ft., *sandstone and limestone drab; quartz grains slightly rounded; calcareous; small grains of porphyry and hematite*	115

5. Porphyry, decomposed, sandstone and limestone. Samples as follows:
   At 231 ft., *clayey material, pink, very fine, calcareous.*
   " 300 ft., *like the above, but coarser, with free quartz and porphyry fragments.*
   " 335 ft., *clayey material, brick-red color; quartz grains, rounded, with red clay between; slightly calcareous.*
   " 342 ft., *grit like that at 153 ft., but not so coarse, slightly calcareous*..... 112
5. Porphyry, *solid, hard*..... 12

Total thickness..... 354

Section XI (No. 11 of Section sheet).

Record of Iron Mountain Drill-Hole No. 13.

Altitude of surface is 1065 feet A. T.

		FT.
1.	Clay.....	17
2.	Sandstone. Samples at various depths are as follows: At 24 ft., *pinkish-gray; fine-grained; strongly effervescent; grains of quartz and porphyry.* " 65 ft., *a coarse grit with sub-angular quartz and decomposed porphyry.* " 95 ft., *a grit, less coarse than the last.* " 130 ft., *a grit like the last, but containing more rounded quartz grains*.....	120
3.	Limestone (?); at a depth of 140 feet, a sample *is of a light gray color, fine-grained, and contains more quartz than lime*.....	47
4.	Sandstone; a sample at 190 feet *is a fine grit with sub-angular quartz grains of reddish-gray color*.....	28
5.	Porphyry decomposed ("wash") and grit. Samples are as follows: At 337 ft., *a coarse grit of quartz and decomposed porphyry, calcareous.* " 240 ft., *like the last, but coarser.* " 246 ft., *like the last.* " 255 ft., *like that at 227 ft.* " 278 ft., "*wash*," *consisting of coarse fragments of porphyry and some quartz*.....	80
6.	Porphyry, *soft*.....	10
7.	Porphyry, *hard*.....	1
	Total thickness.....	303

Section XII.

Record of Iron Mountain Drill-Hole No 14.

Altitude of surface is 1068 feet A. T.

		FT.
1.	Clay and gravel.....	14
2.	Limestone.....	12
3.	Sandstone. Samples at various depths are as follows: At 28 ft., *pink, quartz grains, sub-angular and rounded, of medium size, some porphyry.* " 43 ft., *light gray, finer, more homogeneous than the last.*	

At 72½ ft , *a calcareous sandstone or arenaceous limestone; pinkish gray, fine-grained.*
" 77 ft., *like last, but coarser.*
" 80 ft., "*sand and limestone,*" *grayish-red, very little lime.*
" 86 ft., *a grit of quartz and porphyry fragments.*
" 88 ft., *like the last, but finer, sub-angular quartz grains.*
" 96 ft.. *like the last, but finer.*
" 106 ft., *sandstone, soft, with fragments of porphyry*..... 80

4. Grit and decomposed porphyry. Samples:
At 114 ft., *dark drab, with large particles of porphyry and some quartz grains; slightly calcareous.*
" 128 ft., *like the last.*
" 132 ft., *decomposed porphyry, strongly calcareous on surface of fragments.*
" 139 ft., *porphyry, slightly decomposed, calcareous*..... 33
5. Porphyry, *hard. Sample at 147 feet strongly calcareous*..... 9

Total thickness..... 148

Section XIII.

RECORD OF IRON MOUNTAIN DRILL-HOLE NO. 20 (at sandstone quarry).

Altitude at surface is 1037 feet A. T.

		FT.
1.	Limestone, *light gray color; quartz grain subangular.*	4
2.	Sandstone, *light yellow, gray and white, effervescent, almost a limestone*.....	19
3.	Sandstone, *pink; not calcareous; grains sub-angular*.....	6
4.	Sandstone, *reddish gray; quartz grains sharp or sub-angular, with crystalline faces; mixed with porphyry grains; not calcareous, or slightly so*	40
5.	Sandstone, *pinkish gray; fine-grained, quartz angular, grains of pyrite and some porphyry; strongly calcareous*.....	6
6.	Sandstone, *dull pink, angular quartz grains and fine porphyry grains; non-calcareous*	11
	Total thickness.....	86

A study of these sections reveals a great variability in the character of the rocks, and there is a corresponding and consequent difficulty in the correlation of the different members. As is noted, some of the strata denominated as sandstones are highly calcareous, and might, with well-nigh equal propriety, be termed limestones; with the arenaceous limestones a similar observation is true. An attempt at a correlation is expressed in the following diagram; but it is, confessedly, only approximate. Much of this variability is doubtless due to the marginal position of the sections, situated as they are near the old Iron mountain shore line, where eddies and currents undoubtedly existed in the Paleozoic sea, producing rapid local changes in the strata. But, though we may expect to find less variation away from such mar-

gins, the sections here harmonize with those at other points in indicating a general inconstancy. They further support the general rule that arenaceous layers or grits are the lowest lying members of the thick deposits, and that such generally intervene between the body of the magnesian limestone and the porphyry or granite floor.

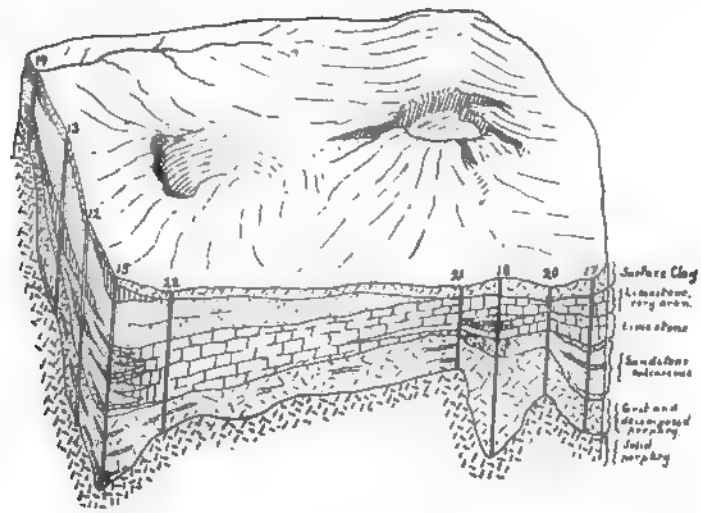

Fig 7. Block map illustrating variability in succession of Paleozoic strata, as revealed by drilling at Iron Mountain

Exposures from which long, continuous sections can be made, do not exist in the vicinity of Iron Mountain, though scattered out-crops are very frequent. Thus, opposite the railway, a quarter of a mile west, is a limestone quarry, exposing magnesian limestone of typical character. The face is 10 or 15 feet high. The rock is coarse and crystalline, characteristically filled with small cavities, lined with dolomite crystals, but containing also large porphyritic illy formed calcite crystals in the mass of the rock. It is of a yellowish color. Analysis No. 5 of page 28 is of rock from here. This limestone is considered to overlie the sandstones exposed in Little mountain, and to be the equivalent of the upper limestone beds noted in Sections IV, V, VI, VII and IX.

Less than half a mile north of here is the sandstone quarry at which the drill hole of section XIII was sunk. The rock exposed is coarse and gritty with numerous small particles of decomposed porphyry. It undoubtedly underlies the limestones to the east, in which direction it dips; in fact, the axis of a gentle anticline, trending east and west, appears at this point.

Less than a mile north of the depot, where the wagon road crosses the railway, a yellowish sandstone crops out in conspicuous ledges. It dips slightly to the west. It must be close to the solid porphyry of Iron mountain to the east, and it contains many fine particles of decomposed porphyry. Similar rock is exposed farther along this road, at the south end of the hill immediately west of the railway at this point. It is also exposed, about 10 feet thick, shaly in part, between the two porphyry hills, just north of the last point, at the middle of the western line of section 30, township 35 N., 4 E. It also occurs and has been quarried about a mile farther north, near the middle of section 19 of the same township. The rock here is very coarsely grained and friable, of a whitish-gray color, with large grains of quartz, and also fragments of light-colored porphyry. The stratum quarried from is about three feet thick, and lies in a nearly horizontal position. Many of the quartz grains of this and other exposures described show crystal faces which are evidently the results of secondary growth.

Belleview Valley.—West of Iron mountain is Buford mountain, and beyond this again is what is known as Belleview valley. This is the largest area of Paleozoic rocks within the limits of the sheet. Numerous exposures of limestone and sandstone are encountered. None of these are, however, of great vertical extent, and opportunities for the construction of long, continuous sections are absent. A series of drill-holes have been put down in this valley, but the writer was unable to obtain records of these for incorporation in this report.

About three-fourths of a mile east of the village of Belleview, the following section is exposed at the fork of the road shown on the map:

Section XIV.

OUT-CROP AT ROAD AND CREEK CROSSING, ¾ mile E. of Belleview.

Altitude of surface is about 980 feet A. T.

		FT.
1.	Limestone, *white, crystalline, thinly bedded, with calcite crystals*	4
2.	Sandstone, *gray, soft, with numerous fine grains of porphyry*	1½
3.	Limestone, *like (1)*	2
4.	Sandstone, *like (2)*	1½
2.	Limestone	1½
	Total thickness	10½

Considering the distance of this section from an Archean area, the rocks exposed must be at least several hundred feet above the base of the Paleozoic column here. The included sandstone beds must hence

be classed among the thin and non-persistent layers of the upper portions of the rock column, which have been recognized elsewhere.

Thence northward, down Cedar creek, out-crops of limestone are frequent. At the ford, three miles due north of Belleview, on the south bank, a bed of sandstone rises from about the level of the creek to a height of from 15 to 20 feet; above this about 15 feet of limestone is exposed.

South of Belleview and along the road thence to Graniteville is a great area of chert-covered "Flint-hills," which rise to an altitude of nearly 1600 hundred feet, or nearly 600 feet above the valley. They are covered with chert in nodular masses, and of irregular size.

Graniteville.—About a mile southwest of Graniteville, approximately at the point designated on the map, a drill-hole was put down to a depth of 350 feet, known as the Sweeney drill-hole. A complete record of this hole could not be obtained, but samples, kindly furnished by Mr. Thos. Beard, of Ironton, were examined by the writer with the following results:

Section XV (No. 12 of Section sheet).

NOTES OF SWEENEY DRILL-HOLE NEAR GRANITEVILLE (S. E. ¼, S. W. ¼, Sec. 15, Twp. 34 N., 4 E.

Altitude of surface is about 1300 feet A. T.

			FT.
1.	Limestone, *magnesian with calcite crystals; coarse, crystalline of open texture,*	at	108
2.	Limestone, *finer grained with silica*	"	110
3.	Limestone, *finer grained with silica*	"	120
4.	Limestone, *like (1), but quartzose*	"	135
5.	Limestone, *like (2)*	"	138
6.	Limestone, *hard, gritty, magnesian*	"	155
7.	Limestone, *dark, fine-grained, magnesian*	"	200
8.	Grit, *coarse, with porphyry fragments*	"	218
9.	Grit, *coarse, with porphyry fragments*	"	219
10.	Grit and shale, *gray and argillaceous*	"	227
11.	Shale, *argillaceous, lighter gray*	"	228
12.	Limestone, *gritty, dark, magnesian.*	"	230
13.	Shale, *gray, dark, argillaceous*	"	238
14.	Limestone, *dolomitic, dark gray, fine-grained*	at	232–237
15.	Grit, *with porphyry fragments*	at	250
16.	Limestone, *magnesian, coarse, open*	"	270
17.	Sandstone, *fine-grained, light drab*	"	298
18.	Grit, *pink, with porphyry fragments.*	"	320
19.	Grit, *coarser, with porphyry fragments*	"	320
20.	Porphyry conglomerate	"	348

East of Graniteville, and immediately south of Middlebrook, is a "Flint hill," referred to on page 30. No section could be measured here. The blocks of chert are remarkable for their great size and massive structure.

About a mile and a half south of Middlebrook, and west of the railway, is an outcrop of sandstone from which stone has been quarried for bridge piers and other local purposes.

Pilot Knob and Vicinity.—The country about Pilot Knob is similarly destitute of any exposures suitable for the measurement of long sections. A large number of drill-holes have, however, been put down here, while prospecting for iron ore, through the limestone rocks into the porphyries. The exact location of these holes is shown on the map on a later page of this report.

Cores of a number of these holes were examined by the writer, and the resuls are incorporated in the following sections:

Section XVI (No. 13 of Section sheet).

NOTES OF PILOT KNOB DRILL-HOLE No. 30 (north end of Shepherd mountain).

Altitude of surface is about 950 feet A. T.

		FT.
1.	Soil and clay.	12
2.	Limestone, *magnesian, crystalline, dark gray, open texture, but of fine texture in places, and somewhat argillaceous.*	31
3.	Limestone, *magnesian, more crystalline, whiter, very open texture, with dolomite and pyrite crystals lining the cavities; lower 8 ft. with some chlorite*	29
4.	Limestone, *magnesian; like (3), but yellowish and drab and of more open texture; cavities lined with dolomite*	30
5.	Limestone, *magnesian, compacter, of finer crystalline texture, lower 10 feet reddish and ferruginous*	30
6.	Limestone, *magnesian; the upper 7 feet red and ferruginous; the next 9 feet gritty, with quartz and porphyry fragments; the next 8 feet gritty but finer, with quartz grains; the next 8 feet fine-grained and homogeneous, with pyrite*	23
7.	Limestone, *magnesian; the upper half pink and somewhat gritty; the lower half finer grained and more argillaceous; minute nodular concretions of pyrite efflorescence of sulphates of iron and magnesia*	29
8.	Limestone, *magnesian, fine-grained and argillaceous; patches of a foot or so contain fragments of decomposed porphyry; at 3 feet from the bottom is an 8-inch streak of drab argillaceous shale*	30
9.	Sandstone and grit, *the upper 20 feet of a light gray color, very fine-grained, containing gritty streaks with porphyry fragments; the lower 7 feet are similar, but of yellow color*	27
10.	Sandstone, *arenaceous, yellowish and gray, fine-grained*	6
11.	Grit and decomposed porphyry passing into solid porphyry.	47
	Total thickness	300

Section XVII (No. 14 of Section sheet).

NOTES OF PILOT KNOB DRILL-HOLE No 38 (north end of Shepherd mountain).

Altitude of surface is about 950 feet A. T.

		FT.
1.	Limestone, *magnesian, white and drab, moderately porous; crystalline, shaly, arenaceous layers in the upper 40 feet; grows pink near bottom*	144
2.	Limestone, *magnesian, gray, finer grained, arenaceous, effervescent*	59
3.	Sandstone *and fine, sandy shale, non-calcareous streaks of drab porphyry grit, especially near the bottom*	34
4.	Sandstone, *or fine, sandy shale, like last, but pinkish drab in color; porphyry grit and boulders near the bottom*	58
	Total thickness	295

Section XVIII (No. 15 of Section sheet).

NOTES OF PILOT KNOB DRILL-HOLE No. 42 (near R'y track, north of town).

Altitude of surface is about 950 feet A. T.

		FT.
1.	Soil, clay and undetermined (reported to be limestone)	122
2.	Sandstone, *yellow near top and gritty with porhpyry fragments near the bottom*	12
3.	Limestone, *magnesian, very arenaceous, almost a sandstone; compact and hard*	15
4.	Limestone, *magnesion like (3), but passing into very fine sandstone at the base*	30
5.	Sandstone, *very fine grained, almost a shale, slightly calcareous*	21
6.	Grit and porphyry conglomerate, *passing into solid porphyry*	25
	Total thickness	225

Section XIX (No. 16 of Section sheet).

NOTES OF PILOT KNOB DRILL-HOLE No. 50 (at lime quarry.)

Altitude of surface is about 960 feet A. T.

		FT.
1.	Soil and clay	14
2.	Limestone, *magnesian, yellowish; coarsely crystalline, calcite crystals abundant; at 26 feet a one-inch layer sandy shale; limestone of open and porous texture*	30
3.	Limestone, *magnesian, similar to (2), no shale beds, but greenish shaly streak near the bottom*	19
4.	Limestone, *magnesian, like (3); contains cavities lined with dolomite crystals upon which are small cubes of pyrite*	12
5.	Limestone, *compacter than (4), gray, hard, marble-like, with patches of red clay*	13
6.	Limestone, *magnesian, pink and reddish color, like (5), but more open and porous, with streaks of deep red shale 6 inches thick.*	64
7.	Limestone, *magnesian like (6), gray and pink; a layer of sandy shale 156 to 158 feet; laminæ of green shale in the limestone*	18
8.	Limestone, *magnesian, more compact and argillaceous than (7); passes downward successively into porphyry grit, conglomerate, and finally into solid porphyry*	46
	Total thickness	216

Section XX (No 17 of Section sheet).

NOTES OF PILOT KNOB DRILL-HOLE No. 45 (west side of Shepherd mountain).

Altitude of surface is about 1040 feet A. T.

		FT.
1.	Soil and clay	16
2.	Limestone, *magnesian; the upper 8 feet dark gray, crystalline and open texture; the next 6 feet dark gray, fine-grained and arenaceous; the next 14 feet light gray, open and crystalline*	28
3.	Limestone, *magnesian, dark and light gray in color; texture somewhat open; shaly, green blotches and streaks; crystalline, like marble in places*	40
4.	Limestone, *magnesian, like (3) but pink and red in color with streaks of red shale; the lowest 4 feet mostly reddish and greenish arenaceous shale with porphyry grit.*	35
5.	Limestone, *magnesian, pink with red streaks and some grit; somewhat open and crystalline*	41
6.	Sandstone and porphyry grit conglomerates	122
7.	Porphyry, *solid*	
	Total thickness	282

Reviewing the results expressed in these sections, we see that we have in all, massive beds of limestone in the upper 200 feet or so. In the drill-hole near the lime quarry, section XIX, we have no sandstone intervening between the limestone and porphyry. This is doubtless due to the fact of its location in a narrow gorge between porphyry hills, into which the introduction of coarse sediments would be difficult. In three other holes, immediately north and west of the knob, we find sandstone beds, represented at depths of about 750 feet, A. T. These are very fine and shaly in texture, but are distinctly arenaceous, and deserve to be classed as transition beds from the limestones into the porphyry grits and conglomerates below. In section XX of a hole located west of Shepherd mountain, sandstone was also found to be present, but here it comes in at an altitude of nearly 900 feet, A. T. Porphyry detritus in the shape of grit, conglomerate and decomposed boulders are represented in all of the holes overlying the massive porphyries.

Ironton and Arcadia Valley.—South and east of Ironton is another great stretch of country underlain by Paleozoic rocks. Our best information here is also derived from the results of drilling. Three diamond drill-holes were put down in the town of Ironton in search of water. Their locations are shown on the topographic map. The following notes upon the rocks encountered are from examinations made by the writer of specimens preserved by Mr. Beard, of Ironton, and kindly presented by him to the Survey:

Section XXI (No. 18 of Section sheet).

NOTES OF IRONTON DRILL-HOLE No. 1 (Jones).

Altitude of surfcce is about 920 feet A. T.

			FT.
1.	Limestone, *magnesian, light yellow, open texture*	at	30
2.	Limestone, *magnesian, like (1), gray color*	"	130
3.	Limestone, *magnesian, light drab color, very fine texture, hard and compact.*	"	250
4.	Shale, *light drab color, arenaceous, fine-grained.*	"	278
5.	Sandstone and grit, *containing quartz grains and fragments of porphyry; calcareous and argillaceous in places.*	"	285
6.	Porphyry grit, *composed largely of porphyry fragments*	"	300
7.	Porphyry conglomerate	"	350

Section XXII (No 19 of Section sheet).

NOTES OF IRONTON DRILL-HOLE No. 2 (Robery).

Altitude of surface about 940 feet A. T.

			FT.
1.	Limestone, *mottled yellowish and red color like marble, somewhat decomposed, open texture, freely effervescent.*	at	20
2.	Grit, *calcareous, consisting of quartz grains surrounded by matrix of magnesian limestone. A very hard, compact rock*	"	30
3.	Grit, *calcareous, like (2)*	"	40
4.	Limestone, *magnesian, very fine-grained, drab*	"	50
5.	Limestone, *magnesian, coarse-grained, pink*	"	100
6.	Limestone, *magnesian, somewhat earthy*	"	150
7.	Limestone, *magnesian, somewhat arenaceous, dark gray and compact*	"	210
8.	Shale, *dark gray, argillaceous*	"	225
9.	Grit, *calcareous, composed of fragments of porphyry and quartz grains*	"	253
10.	Shale, *dark drab, argillaceous*	"	255
11.	Grit *of porphyry fragments*	"	255
12.	Porphyry, *compact*	"	260

Section XXIII (No. 20 of Section sheet).

NOTES OF IRONTON DRILL-HOLE No. 3 (Arcadia Mill Co.)

Altitude of surface is about 1060 feet A. T.

			FT.
1.	Limestone, *magnesian, white, very open texture.*	at	15
2.	Limestone, *magnesian, like (1)*	"	20
3.	Limestone, *magnesian, but very fine-grained and white.*	"	30
4.	Limestone, *magnesian, like (3)*	at	40, 45, 50
5.	Limestone, *magnesian, dull gray color*	"	60, 79
6.	Limestone, *magnesian, gray, fine grained, with calcite vein*	at	100
7.	Shale, *sandy gray with some grit*	"	150
8.	Sandstone, *very fine grained drab color*	"	160
9.	Sandstone *and porphyry grit*	at	195, 200
10.	Grit, *composed chiefly of porphyry fragments, with some grains of quartz and some limestone in the matrix*	at	205, 220, 240, 250, 260, 270, 285, 290

In these holes, as in the preceding ones, most of the upper portions are through massive limestone; while the shales, sandstones and grits are represented near the bottom, at depths varying from 150 to 278 feet and corresponding to altitudes of 650, 720 and 870 feet, A. T., indicating great variability in the sections.

Exposures of limestone are very abundant immediately south of Arcadia, along the railway in its ascent to Tiptop. Still farther south are numerous chert-covered hills, liberally covered with chert fragments, but exposing very few sections.

About a mile west of Ironton, upon the side of Shepherd mountain, about 140 feet above the level of the town, or nearly 1100 feet A. T., is an out-crop of sandstone from which a good deal of stone has been quarried for building purposes in Ironton and vicinity. The total thickness exposed is perhaps 15 feet, largely shaly, with a few thick beds. The stratum quarried from is about 20 inches thick. The sandstone is of coarse texture and composed of quartz and porphyry grains somewhat loosely cemented together. This out-crop must be a remnant of the shore-line portions of a deposit which once overlaid the clastic rocks, now existing in the valley. It may have lost its arenaceous and fragmentary character proceeding from the shore outward, and may even have been represented by a limestone; but it is undoubtedly a sandstone bed belonging higher in the series, or of later age than those encountered at the base of the drill-holes whose records have been given.

About four miles west of Ironton, on the Krammel land, in the southwestern portion of section 2, township 33 N., 3 E., on the side of a creek, is an outcrop of marble exposed in a bluff 10 to 15 feet high. The stone is largely nodular and rough, with red clay filling the cavities between the nodules. The beds of the compact stone range in thickness up to about one foot. They are of gray and pink colors. An analysis of this limestone or marble has already been cited on page 28. Further mention of it will be made later. The altitude of the out-crop is about 1040 feet A. T. It is hence topographically much above the beds of the limestone exposed in Arcadia valley. Structural considerations lead us to believe that it is also above them stratigraphically.

In the southwestern portion of the sheet numerous out-crops of limestone, shale and grit are exposed along the Iron Mountain railway, between Hogan and Tiptop. The limestone itself is, in places, filled

with small fragments of porphyry. Some of the grits are very coarse, while immediately associated with them are very argillaceous shales. The shales are exposed in the railway cut just south of the big curve, at an altitude of about 1100 feet A. T., and immediately adjoining an outcrop of massive porphyry.

CORRELATION AND AGE.

A study of the sections and the other notes just presented, will reveal the fact that a detailed correlation of the members of the widely separated or even adjoining sections, is out of the question. We are forced to the conclusion that the minor differences of material, texture and color are local and extremely variable along the same horizon. A general classification of the rocks occurring within our area is, however, practicable, as has already been indicated. This classification is embodied in the following generallized section.

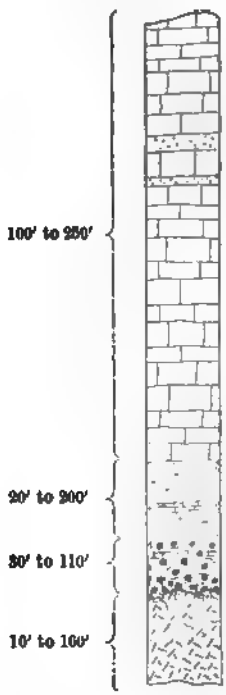

Fig. 8 General section of the Paleozoic rocks

As to the exact age of these Paleozoic rocks, with the exception of the evident fact that they are post-Algonkian, there is no evidence presented within the area of the sheet. Not a single fossil has been found here to the writer's knowledge. For the determination of their age, we are, therefore, dependent upon our interpretation of their stratigraphic relations to the rocks of surrounding areas. Immediately east of the sheet, in Madison county, and north of it in St. Francois county, a few fossils have been found in rocks which we are satisfied belong to the same group as those included in the Iron Mountain sheet. The exact significance of these fossils, we regret to say, is not yet satisfactorily determined. Authorities differ as to whether the

rocks should be assigned to the Cambrian or to the Lower Silurian or Ordovician; the question must therefore be left open for the present. A discussion of the paleontological evidence would be out of place here, and we hence confine ourselves to this general statement of present conditions.

SOURCES OF MATERIAL.

The sources of the materials composing the Paleozoic strata of this region can be none other than the pre-existing Archean or Algonkian rocks around which the former were deposited. In the conglomerates and grits which overlie the solid and massive porphyry or granite, fragments of these older rocks are plainly recognized. In the sandstones which are above these, we find the quartz of the granites represented, and it is significant that the coarser sandstones of this region are found either in the immediate vicinity of a granite area, or in such position that the detritus from the decaying of these granites could be washed to the present sandstone localities.

In the arenaceous shales we have represented the smaller quartz grains of the granites, as well as the minute particles, or phenocrysts, of quartz which are recognized in the porphyries; the extremely fine texture of the sandstones near the base of the series in the vicinity of Pilot knob is most probably due to the fact of the smallness of the quartz grains or crystals in the surrounding porphyries. In the argillaceous shales we have represented the clay products from the decay of the feldspathic rocks; while in the great massive beds of limestone we have represented the calcareous and magnesian constituents which passed into solution and were redeposited through chemical or organic agencies. How great the time, how vast the amount of decay of these firm and resistant rocks in order that this great volume of sedimentary material could be accumulated, cannot be readily pictured.

DYNAMICAL GEOLOGY.

Structure.—The Paleozoic rocks of the Iron Mountain sheet present very little evidence of disturbance or movement. The beds within the larger areas, away from the Archean hills, generally lie in a horizontal position; slight flexures are, however, apparent at times, but these are not persistent. Around the sides of the Archean hills the rocks invariably dip away from such centers, and this has been attri-

buted by some to a vertical movement of the older crystalline rocks. This conclusion does not seem, however, to be well founded; the phenomenon has all the appearance of being due principally, if not entirely, to the fact that the beds were deposited on the sloping floor of the submerged hill. Under these conditions they would naturally slope away from the hill as a center. The invariableness of these conditions corroborates the conclusions herein expressed, as does also the fact that the strata taper out successively up the slope of the hill. It is hardly possible to conceive of these hills having been moved vertically upward without the surrounding rocks being disturbed, and thus the horizontality of the strata in the valleys is against any such movement having taken place. Therefore, the subject may be dismissed with the remark that there is only such flexing or irregularity in the attitude of these rocks as can be accounted for by the inequalities of the floor upon which they were laid down, or by the settling of the rocks after their deposition, supplemented perhaps by a gentle oscillation during the regional uplift which brought these rocks above the surface of the water.

Sub-areal Decay and Original Thickness.—The great sub-areal decay of the rocks of this region has already been treated of in this report. The fact that remnants of the Paleozoic rocks are found within the area, at an altitude of nearly 1600 feet (see page 28), whereas at other points their limits are as low as 1000 feet A. T., indicates what a vast amount of rock has been removed. The products or residues of this decay are clay, sand, chert in nodules and large blocks, and indurated sandstone. Over a large part of the country, as has already been referred to, there are great accumulations of chert nodules, which have given to the hills covered by them the name of "Flint hills." Over portions protected from vigorous erosion, accumulations of residuary clay exist and are encountered in excavations. In the railway cut at Tiptop, about five miles south of Ironton, a great body of such clay is exposed to a thickness of 30 feet or more. It is made up of different materials; part is apparently of clay proper, a large portion of which is of a yellow and drab color, while along the seams it is of a white color, like true kaolin. An analysis of a specimen of this clay showed, however, that it is composed in large part of silica, even the white kaolin-like portion containing over 60 per cent. The following results show its composition:

ANALYSIS OF CLAYS FROM TIPTOP.

J. D. Robertson, Anal.

Mixture of white and yellow clays.

SiO_2	90.05
Al_2O_3	4.63
Fe_2O_3	2.31
CaO	trace
MgO	trace
Loss on ignition	2.72
	99.71

A large part of the deposit is sand, which occurs in strata-like beds dipping at a high angle to the south, and, further, blocks and fragments of white quartzite and nodules of quartz are included in this mass.

It is impossible at the present writing to fix the exact upper limit reached by these sedimentary beds. They probably extended somewhat above the highest limit noted, but we are inclined to think that they did not go very far beyond this. Our principal reason for this conclusion is the fact of the entire absence of any of their remains overlying any of the porphyry hills which reach the altitude of 1800 ft. A. T. Of course, these summits have been subjected to vigorous erosive action; but yet we are inclined to think that, if the cherty upper members of the series had ever covered such hills, some of this almost indestructible chert would remain to bear witness of the fact. As we go farther west, toward the limit of the Archean area, such remnants are found on the flat tops of the porphyry hills, even though the sides are destitute of them.

Metamorphism.—Strictly speaking, we are not inclined to class these strata among metamorphosed rocks, in the sense that they have been altered or indurated by an excessive amount of heat. There is entire absence of any evidence that great heat has anything to do with their present condition. There have been no igneous rocks ejected in their vicinity since their formation; there have been no violent or great orographic movements; they have never been buried deep enough beneath superincumbent strata for subterranean heat to have altered them. Their present highly crystalline or indurated condition is, in the writer's opinion, due almost entirely to the action of percolating waters, which also could have affected their dolomization; the open, porous structure of many of the massive beds would be a natural result of the reduction in volume caused by the substitution of carbonate of magnesia for carbonate of lime.

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The marbles of this and adjoining areas have been adduced by some as additional evidence of metamorphic action. As has already been intimated on page 30, we do not consider them necessarily such. These marbles are not truly crystallized limestones, composed of well-defined and separate crystals; they are more properly dense crystalline limestones, variously tinted and susceptible of polish. The differences in structures and properties between these rocks and the surrounding dolomites may well be attributed to the difference in composition shown on page 28.

ECONOMIC GEOLOGY.

The minerals of greatest economic value within the limits of the sheet are iron ores and building stones. Lead ores are mined near the northeastern corner, but, though the town of Doe Run is within the boundary lines, the main deposit of ore is just beyond the limits, and will be more appropriately described in connection with the deposits of Mine LaMotte of the adjoining sheet. Clays, limes and sands of value for ordinary local uses are also found and will receive brief treatment.

THE IRON ORES.

By Frank L. Nason.

The St. Francois mountains have a world-wide reputation as producers of iron ores; yet, notwithstanding the great areal extent of the porphyry and granite rocks which make up the mass of the mountains, their reputation depends principally upon two localities. These two localities are at Iron Mountain and Pilot Knob. There are other specular ore deposits in the vicinity of these two great deposits, but these sink into insignificance in comparison with the first named.

Iron Mountain has produced, in round numbers, 3,500,000 tons; Pilot Knob, about 1,500,000 tons.[1] The amounts of ore produced at other localities are as follows: Shepherd mountain, 75,000 tons; Cedar mountain, 25,000 tons; Buford mountain, 3000 tons; Russell mountain, 3000 tons; Shut-In, 600 tons. This gives a total of 5,106,600 tons. Of this amount Iron Mountain has produced 68½%; Pilot Knob 29%;

[1] The records at Pilot Knob prior to 1882 were destroyed by fire. From 1882 to 1892 inclusive, Pilot Knob has produced 1,074,000 tons. This and much of the data in the following descriptions have been obtained through the kindness of Prof. W. B. Potter, of St. Louis, the engineer of the Iron Mountain company.

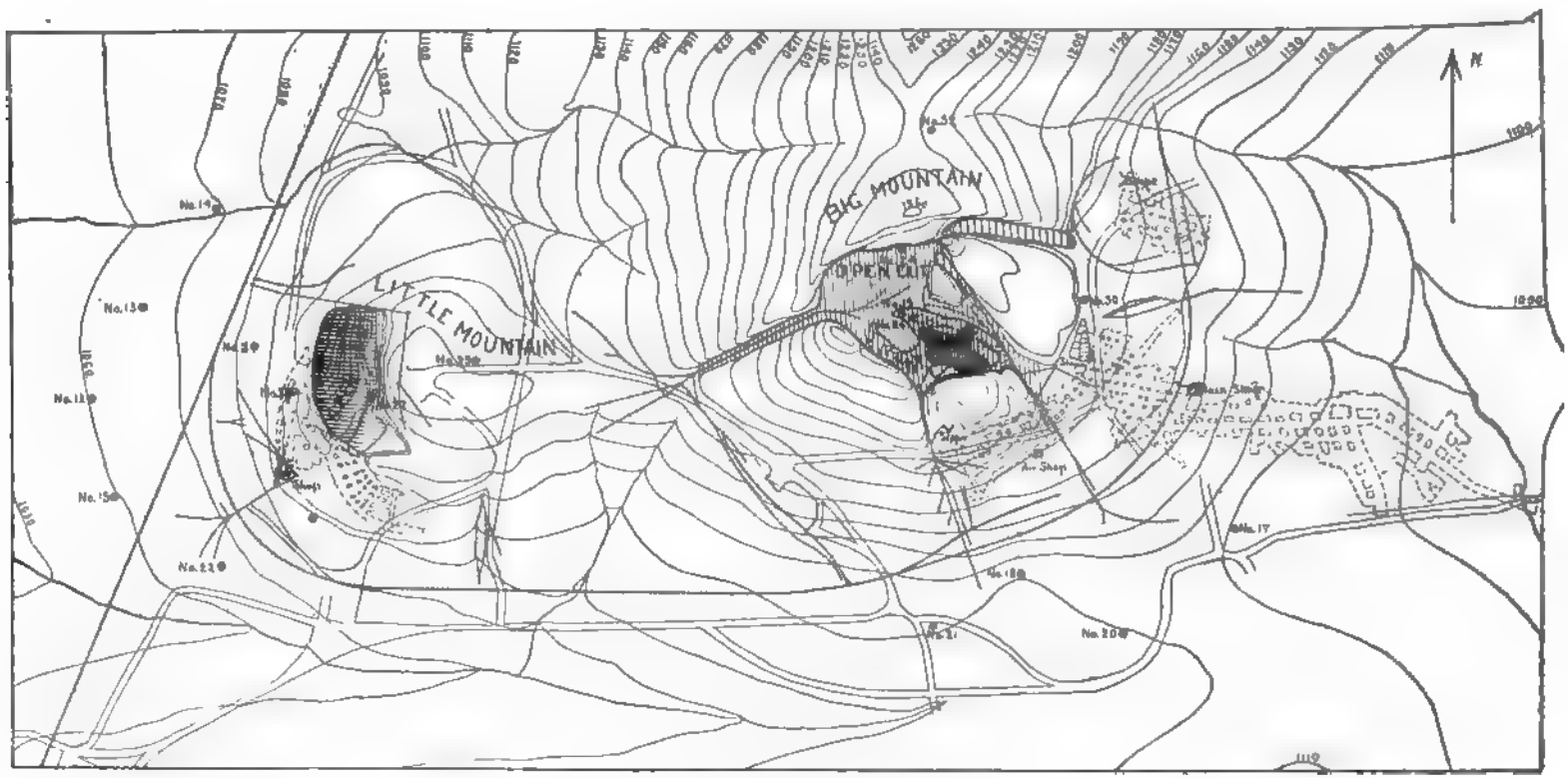


Fig. 9. A contoured map of the Iron Mountain mine.

Cross-lined areas are open cuts, the thickness of the cross lines being proportional to the depth of the cut.
Small circles with black centers are drill-holes; the accompanying numbers are those of the Iron Mountain company.
Underground workings are shown by broken lines.

Datum of contours is sea level. **Scale is 600 = 1 in.**

the remaining localities 2½%. It will thus be seen that the statement with regard to the relative amounts produced is true, and that the reputation of the St. Francois mountains as iron-ore producers depends practically upon Iron Mountain and Pilot Knob.

IRON MOUNTAIN.

The Iron Mountain deposit of specular ore is located in St. Francois county, in section 31, township 35 N., 4 E. It is 81 miles south of St. Louis on the St. Louis, Iron Mountain & Southern railway.

The highest point of the mountain at the mine is known as the Big mountain, and rises about 200 feet above the level of the surrounding valley; west of Big mountain is a lower hill known as Little mountain. The highest point of Little mountain is 130 feet lower than Big mountain. There is, however, really no topographical distinction between the two, Little mountain being but a shoulder of the larger mountain, and both are but lower points of a larger porphyry mountain which reaches to the north. These and other features of the mine are well shown on the topographic map of the mine on the preceding page.

It is on these two points that the ore deposit is found which gave the locality its name. When first discovered, the mountain, for it will be referred to by this singular noun, was completely covered by boulders of specular ore of various sizes, some of them weighing many tons each. No rock was in sight, and this led to the idea, which was only dispelled by long working, that the entire elevation was of solid iron ore, and it was fully believed that this ore extended indefinitely downward. This idea was strictly in accord with the tenets of geology as they were then taught, that metalliferous veins, including iron ores, were of eruptive origin, and their source being deep within the earth, the size of a given deposit would increase rather than diminish as the workings grew in depth. It is not necessary to add that this idea has long since given way, as observations have increased, leading to a more correct interpretation of geological facts.

The working of this deposit was first carried on in the boulders entirely. Work on the Big mountain finally exhausted the boulders in places and they were found to rest, together with the clays which filled the interstices of the boulders, upon solid masses of iron ore in some places, and, in others, upon a decomposed porphyry rock which changed with depth into the solid porphyry of the surrounding hills. Gradually, as the work extended, the limits of the solid iron ore were found,

and the exploration also showed limits to the boulder deposits, which were themselves at first thought to be inexhaustible. The boulder deposits were found to lie in a thick mantle over the summit and slope of the mountain. This mantle was heaviest near the highest point and gradually thinned out as the lower flanks of the mountain were reached. Not only did the deposit grow thinner at the flanks, but it was found that the boulders were interstratified with thick layers of tough reddish clay with but occasional lumps of iron imbedded, and these of diminished size.

The stripping of the mountain showed still another feature. On the eastern and western slopes especially, the point was reached where the Paleozoic rocks were found to rest upon a deposit of iron ore and porphyry boulders. This discovery showed conclusively that the age of the iron ore veins as well as of this last boulder deposit was greater than the sandstones and limestones which surrounded the mountain in which the ore was found. In the surface mantle were found clays of a different color and texture. In these clays were fragments of specular iron, but in addition there were fragments of chert, showing clearly that these clays were a residuum of a decomposed limestone; while the boulder deposit plainly pointed to the conclusion that, while the Paleozoic seas were washing the foot of the mountain, disintegration was at work on this ore-body, and that occasional fragments would roll down from the parent mass and become imbedded in the sediments. Still further is this shown to be the case by the finding of iron fragments imbedded in the undecomposed limestones, but the strongest proof of all lies in the great boulder deposits, which, on the eastern side of the mountain, reach for over 1200 feet along the base of the Paleozoic rocks.

Reviewing the above, we find the following series of deposits of iron ore at Iron Mountain: First, the superficial boulder deposit; second, the solid ore-vein deposits; and third, the early Paleozoic boulders. These will be described in the order given.

As has been stated, the mantle of ore nowhere exceeded twenty feet in thickness, and, upon the removal of this, the true nature of the deposit was revealed, although its extent was still uncertain. The solid ore, which must be regarded as the parent mass, was found to extend in a perfect net-work of reticulating veins of various size, but

with a general northeast trend. The nature of the veins is shown in the following cut, which illustrates the appearance of the breast of ore worked just south of drill hole No. 23, located on the map opposite p. 55. The "bluff" which fills the spaces between the solid veins of iron is more or less decomposed porphyry. This cut shows the lateral veins, as they may be called. The main vein ran nearly due northeast across the mountain. A cross-section of this main vein [Fig. 11] called the backbone vein, shows its comparatively great size, and also shows what is known as a saddle-back among miners. The legs of this vein are here from twelve to eighteen feet thick. The space between the two legs is filled with broken ore and porphyry. This vein extended through what is now an open cut and which is marked as such on the topographical map of the mountain. The "open cut" is about 480 feet wide north and south. The lowest point to which the ore has been excavated is about 150 feet below the highest point of this mountain. The whole pit has not been sunk to a common level on account of the subdivision of the main or backbone vein.

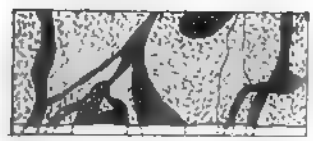


Fig. 10. Veins of specular iron ore in porphyry at Iron mountain

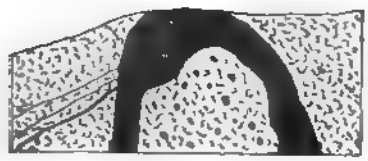


Fig. 11. Section of the main vein at Iron mountain.

On Little mountain, a vein about 420 feet long on the outcrop was found. The entire depth of this ore body, measured on a slope of about 40°, is 360 feet. The thickness from foot to hanging wall is about 30 feet, with a maximum of 40 feet. Workings which extend underground toward the south and east reach about 240 feet farther. The outlines of these underground workings are shown in the topographical map of the mine by the broken lines. The foot-wall of this vein is not clean and sharp, but is made up of brecciated porphyry, with the interstices filled principally with iron ore, but also with quartz and apatite crystals, with occasional crystals of hornblende. The immediate hanging wall is made up of boulder-like masses, embedded in more or less indurated clay. Over this lies the Paleozoic limestone.

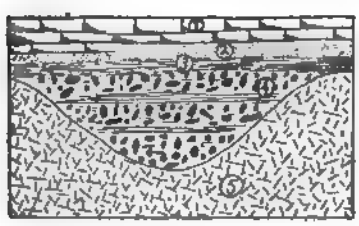
There is a wide break between Little and Big mountains, and the vein seems to disappear east of Big mountain, near bore-hole No. 30, shown on the map. West of Little mountain bore-holes Nos. 27, 28, 2, 22, 15, 12, 13 and 14 have failed to show either a solid vein or a workable deposit of boulders. Bore-holes Nos. 32, 30, 17, 20, 21, 18, etc.,

also fail to show extensions of large veins, and it seems probable that the first line of detrital ore marked out quite accurately the direction and extent of the veins, although the veins have not proved to be continuous.

Fig 12 Section showing relations of conglomerate beds to limestone.

The next and last of the economically important deposits at Iron Mountain are the beds of boulder or detrital ore. These are found exclusively, thus far, on the eastern slope of Big mountain. The underground workings of these deposits here are accurately outlined by broken lines on the contoured map. As is there shown, they extend about 1680 feet from the mouth of the slope eastward.

Fig. 12 shows the relation of the conglomerate beds to the Paleozoic rocks and the porphyry foot wall. At the point where the section is taken the conglomerate ore is immediately overlain by a bluish green or gray decomposed porphyry clay, with boulders of partially decomposed porphyry. There are only occasional fragments of iron ore in this. The strata between those of ore are of the same nature, as is also the interstitial filling between the iron ore boulders. Over all are beds of limestone.



1. *Magnesian limestone.*
2. *Sandstone*
3. *Clay shale*
4. *Deposit of boulder ore*
5. *More or less decomposed porphyry.*

Fig. 13. Diagram illustrating channel form of boulder deposits.

The extreme width of this deposit, so far as is known, is about 360′. The height from foot to hanging wall is about 20 feet. This thickness does not hold throughout, however, but the foot and hanging walls come together quite rapidly on either side. The adjoining ideal cross section illustrates this.

The boulders of iron are held tightly in a partially indurated clay, in which are also boulders of porphyry and a jaspery rock which is still very fresh. The beds are so firm that shooting is necessary in mining. The firmness of the masses is well illustrated by the relative sizes of the galleries and pillars as shown in mine map.

The boulders of ore as mined vary from sizes as small as peas up to masses weighing 100 pounds and more; all of these are well rounded.

It is hardly necessary to state that there are no deposits which rank higher than this of Iron mountain. If accessibility and ease of mining be taken into account, its competitors must still more be reduced. The early development was done when iron was not in great demand. Thus a large part of the deposit was mined in time to take advantage of the brisk markets for ore between 1870 to 1880. In this decade many thousands of tons were sold at $10 per ton and orders were filled at $15. Fully 66% of the ore at Iron mountain was mined between 1870 and 1890, and the greater part of this from 1870 to 1886.

The composition of the ores of Iron mountain presents rather a wide range as to the amounts of phosphorus, as the following analyses show:

	1	2	3	4	5
Metallic iron	66.93	59.06	65.57	64.67	62.84
Phosphorus	0.071	0.398	0.032	0.019	0.005
Phosphorus ratio	0.106	0.674	0.049	0.029	0.008

No. 1 is from the main vein; No. 2, from same vein nearer the porphyry, and contained visible crystals of apatite; No. 3 is a sample of surface ore; No. 4 is from the surface near the main vein on Big mountain; No. 5, from the surface of Little mountain.

The silica is rarely high; the highest given is 11.68%, the lowest 2.51%. The above partial analyses are fairly representative.

It is a little remarkable that the smaller veins and the part of the large veins near the contact with the porphyry walls contain the highest percents of phosphorus. Why the solid veins should contain the highest phosphorus is more easily understood. Many places in the more exposed parts of the veins are honey-combed with cavities from which crystals of apatite have been removed by weathering, and, on following such a surface downward to a point remote from weathering influences, quite fresh crystals are found. From the boulder ore, both of the surface and the lower Paleozoic, almost the last vestige of phosphorus has been removed, while the silica is remarkably low. At the point where the veins begin to give out, the ore grows lean and silicious through the admixture of porphyry and of quartz crystals and grains which are included in the vein matter.

As the map shows, numerous bore-holes have been put down, which reached depths of from one to three hundred feet. These usually start in a net-work of small veins of ore. As depth is gained the

veins grow fewer as the fresher porphyry is reached, and, though they have not wholly disappeared in every case at the bottom of the holes, they seem to prove conclusively that no rich veins lie below. These holes have been put down so systematically and carefully that it is hardly possible that a rich and extensive deposit, either vein or detrital, could have escaped detection. It seems, therefore, a fact, though much to be deplored, that these test-holes point to the conclusion that the glory of Iron mountain is of the past.

BUFORD MOUNTAIN.

About one mile west of Iron mountain is a large porphyry hill known as Buford mountain (shown on the map). Considerable "float" ore has led to the discovery of small and unimportant veins of iron in the porphyry. No work of development has been done, as the place does not seem to be of sufficient promise. It is expected, however, that a series of drill-holes will be extended across from Iron mountain to Buford. These prospect holes will reach into the porphyry through the overlying Paleozoic rocks of the intermediate valley. If the veins which show up in Buford mountain enlarge in the valley it is hoped thus to strike them. On the other hand, if the known small veins are but the remains of once greater veins, it is thought that conglomerate deposits will be found similar to those at Iron mountain.

PILOT KNOB.

This famous deposit is situated six miles south of Iron mountain. As is shown in the illustration on the next page, it is in a nearly conical hill rising 1521 above tide and 662 above the surrounding valley. The knob stands almost completely isolated from the surrounding porphyry hills, being connected on its eastern side by a neck of porphyry only 200 feet above the surrounding valley. Unlike the porphyry hills in general, the rocks of this hill are distinctly stratified near the summit. The beds have a dip of about 13° to the southwest. It is in this distinctly stratified part of the knob that the deposit of specular ore is found. The cross sections of the section sheet accompanying this report show very well the relations of the ore body to its enclosing rock, while the topographic features of the knob are shown in the cut of the opposite page constructed from maps prepared by Prof. Potter. There are comparatively few exposures of the porphyry below the outcrop of the ore-bed. The surface of the hill is covered by a heavy mantle of the

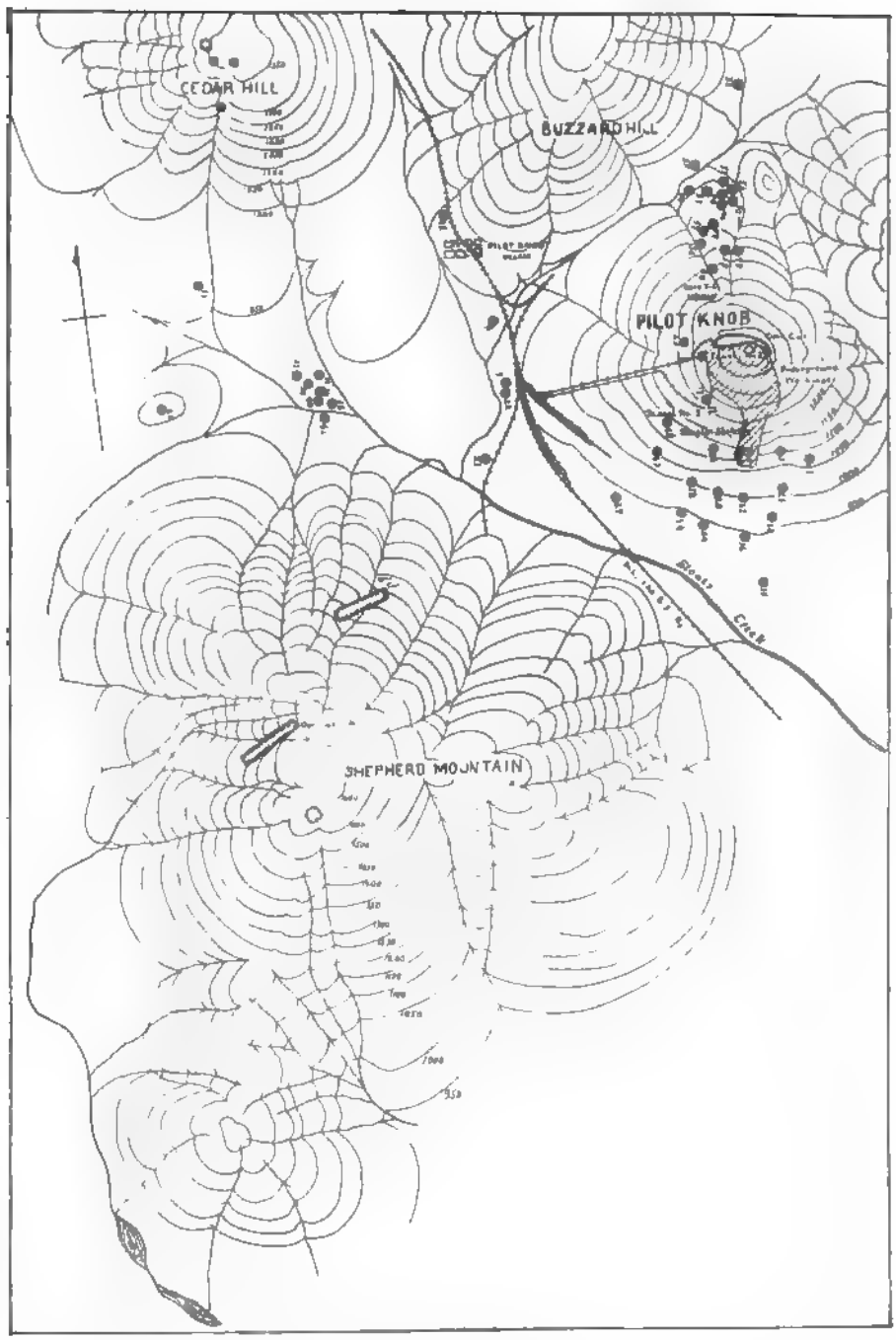


Fig 14. A contoured map of Pilot Knob and vicinity

The cross-lined area shows the extent of mining on Pilot knob Small circles with black centers are drill-holes; the accompanying numbers are those of the Pilot Knob company.
Datum of contours is sea level. Scale is 2500 ft. = 1 in.

residuary clay. This clay is of two kinds: first, the clay which is the residuum of the decomposing porphyry, and second, the residuary clays of the Paleozoic limestones which once reached high up the sides of the knob.

Scattered over the surface, so thickly as at times to wholly obscure the soil, are fragments of porphyry of various sizes. These porphyry fragments are, in places, thickly sprinkled with boulders and fragments of specular ore which have become detached from the parent lode, and have rolled down the steep sides of the hill. If a pit be dug in these surface materials to the solid rock, it will be found that the rock and ore fragments are imbedded in the clay as well as scattered about on the surface of the hill. On the northwestern slope of the hill the ore fragments constitute such a large per cent of the entire mass that it has been found profitable to separate the ore. This fragmental ore is traced more or less abundantly down the slope to near the limestones, and bore-holes through the limestones in the narrow valley between Pilot knob and Buzzard mountain seem to show that this detrital deposit extends under the limestones as do the detrital deposits at Iron Mountain.

Ascending the uniformly steep grade of the hill to about 150 feet of the summit, we come to the deposits which have given the mountain its reputation. At this point the clays and detrital covering cease and we are led by a series of precipitous rocky bluffs to the summit of the knob.

The first rocks which crop out below the ore-body are unmistakably of a porphyritic nature. At first sight they seem to differ in no material respect from the other porphyries in this region; but closer inspection, however, shows them not to be perfectly homogeneous, but to be made up of fragments of various sizes and shapes and to be characterized by bedding planes. As we approach the ore-body these bedding planes become more and more distinct till the porphyry characteristics wholly fade and are succeeded by alternating beds of siliceous and ferruginous slate, the silica being in the form of more or less rounded grains of sand, and these with thin bands of good ore. The foot-wall proper of the ore-body is marked with rugose bands having the appearance of ripple-marks, which they undoubtedly are.

Next in order of upward ascension is the ore-body proper. This, as mining operations have shown, is from 19 to 29 feet thick. It is remarkably homogeneous, having only occasional slaty siliceous seams

or thin beds, and has in a slight degree the variations in thickness which are characteristic of any bedded deposit. The ore body itself is decidedly slaty in structure, with numerous jointing planes. Lying immediately over the ore body, into which it occasionally passes by insensible gradations, is a bed of ferruginous slate. In places this slate is only a few feet thick, but toward the eastern side of the ore body it thickens at the expense of the ore, which thins out to a small bed. The opposite cut gives an idea of the appearance of the slate.

Still ascending, we note that the slates gradually give way to a more thickly bedded deposit, which, instead of the fine grain of the slate, partakes more of the nature of a conglomerate. The conglomerate characteristics increase till, within a few feet above the slate, the beds consist wholly of a coarse breccia, which holds its own to the summit of the knob. There is much iron present in the matrix of this conglomerate; in fact a good part of it could be used as a low grade of ore, were it not for its association with coarser material.

The general appearance of the knob being thus described, we can now take up the more detailed description of the iron ore body. The ore of Pilot knob differs very essentially in its physical aspects from the ore of Iron mountain. It will be remembered that the ore of Iron mountain is very coarsely crystalline, though compact and dense. The Pilot knob ore, on the contrary, is fine grained, hardly ever showing a trace of the coarse crystal faces of the other, and is just as compact and dense as the Iron mountain ore. Another material point of difference is in its structure. The Iron mountain ore is massive—that is, it breaks like granite—while the Pilot knob ore has more of a slaty structure, which causes it to split quite readily. This peculiarity is more plainly noticeable in the detrital ores which are found in the talus on the northwestern slope of the knob. This ore, on weathering, breaks very readily along planes which are scarcely discernible in the ore freshly mined from the bed. Another peculiarity is in the silica contents which are very evenly disseminated throughout its mass. Phosphorus, a very undesirable element, is also present in remarkably small quantities, and is uniformly distributed through the entire ore body. The following partial analyses of the Pilot knob ores show this even distribution of phosphorus. No. 1 is of the highest grade, and No. 2 of the lower grade of ore as shipped :

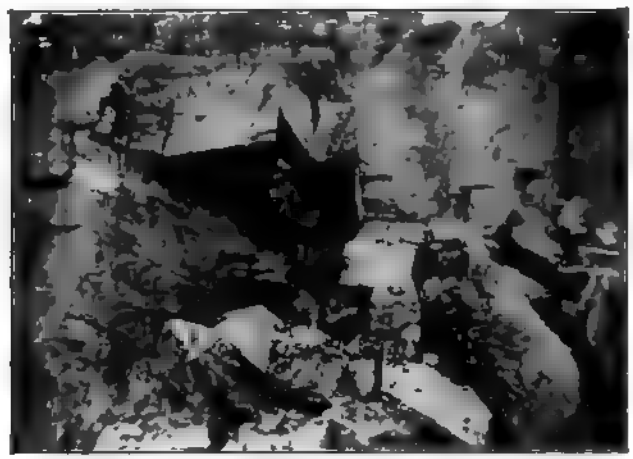


FIG. 1.

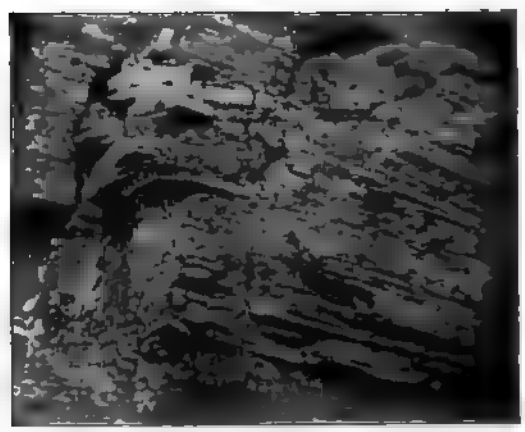


FIG. 2.

Views illustrating the slaty structure of the hanging walls at Pilot Knob.

Reproduced from photographs by F. L. N.

	No. 1.	No. 2.
Metallic iron.....	66.83	43.03
Silica.....	3.62	30.65
Sulphur.....	0.07	0.098
Phosphorus.....	0.014	0.021

These analyses represent large shipments. and may be taken as representatives of their respective grades. While their dense, compact structure and rather high percent of silica, especially in the No. 2 grade, made the ores very refractory and hard to work, their very constant composition and uniformly low per cent in phosphorus made them very eagerly sought for, especially by manufacturers of Bessemer pig iron. The ore body near the foot wall was often interstratified with siliceous seams, and, at times, the silica ran so high as to prohibit the use of the ore. There were also some highly siliceous seams in the main ore body, but these were a small per cent of the total.

The shape of the ore body is roughly pear-shaped, with the longest axis extending north and south and with the stem end toward the south. The thickest part as mined out was twenty-nine feet. The body did not hold this thickness east and west, but showed a strong tendency to thin out, especially on the eastern edge. The western edge held its thickness remarkably well; but, while holding this thickness, it "leaned out" very rapidly, forming a rather abrupt wall on the west. As mining proceeded toward the southern side the walls came together quite rapidly, though the ore still retained nearly the same vertical thickness. Farther south, however, in the Simpson shaft, it is of much diminished size. The general shape of the ore body is well shown in the map on page 62.

Before the mine was exhausted, numerous diamond drill holes were bored both in the porphyry and through the limestones at the foot of the knob. No workable ore was found in the porphyry in this exploration, but in the valleys detrital ore was found, in places in considerable abundance. The results of these borings were communicated through the kindness of Prof. Wm. B. Potter, who conducted the examinations for the company. The drills showed between Pilot knob and Buzzard mountain an area of about 400,000 square feet, underlain by deposits of workable detrital ore, about 200 feet below the surface. The cores brought up by the drill showed the ore to be as free from sulphur and phosphorus as the main deposit of ore on the knob, but it appeared to be much leaner. On this account, as well as because of the low

prices which are now paid for iron, no more work has been done. Farther up the slope of the mountain, *above* the line of the Paleozoic rocks, a detrital deposit is being worked. It is probable that the ore shown by the drills, as lying under the limestone, is a continuation of this deposit.

SHEPHERD MOUNTAIN.

The Shepherd mountain deposit lies about one mile distant from Pilot knob in a west-southwest direction, as is shown in the preceding topographic sketch. Though lying so near, not only the ore deposit, but the country rock also, is wholly different. The country rock of Pilot knob is stratified and of sedimentary origin; that of Shepherd mountain is unstratified and is probably of eruptive origin. The ore of Pilot knob is interstratified with the rock, a bedded deposit; that of Shepherd mountain is a vein formation and cuts across the rocks. The greatest dimension of the Pilot knob bed is in a horizontal direction; that of Shepherd mountain is vertical. The ores of Pilot knob are slaty; those of Shepherd mountain are massive and coarsely crystalline. In short, the nature of the rocks and ores puts Shepherd mountain in closer relationship with Iron mountain rather than with its nearer neighbor.

It will be remembered that at Iron Mountain the porphyry was almost wholly decomposed, covering the surface with a thick mantle of clay, in which were mingled the boulders of iron ore. On the whole mountain scarcely a rock is in sight save when excavation has found it. Shepherd mountain, on the contrary, is exceedingly rocky. Ledges of porphyry are frequently exposed, and, in many places, the surface is covered with fragments of the rock. Near the foot of the mountain, however, there is quite a heavy mantle of clay. The deposit of boulder iron is, however, very limited. On the western and northwestern slopes there is quite an abundance of boulders, sub-angular and smooth, as if water-worn. These boulders are, many of them, highly magnetic. They have never been found in sufficient quantities to pay for working.

The open cuts shown on the map on page 62 indicate the position and direction of the veins. The upper cut is the one which mining showed to be the most valuable. It was opened up for a length of about 1000 feet. When visited in 1891, the rocks were in such a state as to prevent measurements of the veins being made. The excavations showed, however, that it swelled and pinched in such a way as

to make the mining of the ore difficult and expensive. In places the vein ore was mingled with fragments of porphyry, and occasional "horses" of beautifully banded porphyry occurred. Separating the ore from the walls were selvages of white and red clay. Although four or five veins were found, only one was worked to any extent, and this at a loss. Only about 75,000 tons of ore altogether were mined from this place.

From the fact that Shepherd mountain consists of a coarser grained porphyry, and that its veins are as numerous as those of Iron mountain, one would infer that it had suffered a greater amount of erosion, and that this erosion had almost wholly removed the veins formerly enclosed in the porphyry. In such a case one would naturally expect to find boulder deposits as extensive and under the same conditions as those at Iron mountain. As a matter of fact, however, they have not been found. The shallow clays on the upper part of the mountain preclude the possibility of the existence of large beds of boulders, while on the lower slopes test-pits and drill-holes have likewise shown their absence.

At the northeastern foot of the mountain, several diamond-drill holes were put down for two purposes: First, to see if a boulder deposit existed; second, to determine whether the veins extended down the mountain and under the Paleozoic rocks. So far as the first object was concerned, the search was unsuccessful. A deposit of ore was, however, found in the porphyry of considerable extent. An analysis of the ore brought up by the drill showed high percentages of phosphorus and sulphur, and was otherwise so undesirable that, although the drills seemed to indicate a deposit of considerable extent, nothing farther has been done with it.

The Shepherd mountain ores as mined from the veins detracted nothing from the high standing of the porphyry ores generally. They were a high grade Bessemer ore. In silica they were generally higher than those of Pilot knob and Iron mountain, but, as the following analysis shows, they were otherwise equally desirable:

ANALYSIS OF SHEPHERD MOUNTAIN ORE.

Insoluble matter	6.76
Metallic iron	64.31
Sulphur	0.00
Phosphorus	0.017

CEDAR MOUNTAIN.

Cedar mountain lies one mile west of Pilot knob, and its ores resemble more closely those of that place than they do any other of the porphyry ores. The porphyry of Cedar mountain does not differ essentially from the typical rock of the St. Francois mountains. Toward the summit, however, there is a tendency toward stratification and in places there is a distinct conglomeratic structure. The color of the conglomerate is the same as that on Pilot knob, and the more slaty rock has the same bluish color due to the scattered flakes of hematite.

In September, 1872, according to Dr. Schmidt, about two acres were stripped of soil. This resulted in showing up two deposits of ore from one to four feet in width and about 100 feet long. These were diligently prospected, but have not yielded any valuable results; the smaller deposits did not, as was hoped, lead to larger veins or beds. The total yield of ore did not exceed 25,000 tons.

The ore from a metallurgical standpoint was fully up to the best of the porphyry ores.

THE SHUT-IN.

Another deposit of specular ore is found in the "Shut-In," east of Ironton, located on the map. According to Prof. Swallow, one of the earliest furnaces for smelting iron was erected at this place in 1815 or 1816. The place takes its name, as already described in this report, from the fact that Stout's creek here cuts through a narrow gorge in the porphyry rocks. The ore occurs in narrow veins running through the porphyry. One vein has been quite thoroughly tested. According to Dr. Litton it is nearly vertical, with a north and south course. The ore is of excellent quality, but, unfortunately, the vein is only about one foot in width. Other small veins have been found, but none of very great importance.

THE BUILDING STONES.

By G. E. Ladd.

The building stones of this and the surrounding country have already received quite full treatment by the State Geological Survey in a paper by Mr. G. E. Ladd, published in Bulletin No. 1. Little can now be added to this article; but, inasmuch as a description of the building stones is necessary for the completeness of this report, and,

further, as the edition of Bulletin No. 1 is now exhausted, we republish here that part of Mr. Ladd's article which relates to the Iron Mountain sheet:

THE GRANITES.

These rocks have many qualities to recommend them, which are apparent on cursory observation. The colors are excellent, varying from red and pink to gray, while often a contrast between the colors of the constituent minerals yields very beautiful effects. They take a brilliant polish, are very strong and are reasonably durable. Other considerations which make these granites valuable lie in the conditions under which they occur, and these conditions probably hold over extensive areas. The first of these is, that the joint-planes or open seams in the rock are in number and arrangement so happily adjusted as to make the quarrying of the rock easy and economical. The second is that very little "stripping" has to be removed before stone quarrying may be carried on. Further, the stones are easily split by the quarryman, and are easily dressed by the stone-cutter.

The localities where the granite is workable, although not immediately accessible to the railway, can be reached in most cases by switches and tramways. The demand for these granites for building purposes and for paving blocks seems to be constantly growing. The principal markets are St. Louis and Chicago, but the stone has found its way to many distant parts of the United States.

Graniteville.—In township 34, N., 3 E., on the southern half of the line dividing sections 10 and 11, are two quarries which have been operated since 1882 by the "Syenite Granite" company. These quarries are probably the largest in the state. They are admirably located on hill slopes, which location permits of their being drained by siphons. The rock is a red granite, exposed in extensive out-crops, generally with a thin cover necessitating little stripping. It is very easily quarried, having a good "bedding" plane, and vertical joint-planes in sufficient quantities to assist the quarryman greatly in setting out stone; and yet not so abundant as to prevent the obtaining of very large blocks. The color of this stone is red or dark pink, mottled with gray and black—the red shades being due to feldspar, the other to a more or less smoky quartz. The rock takes a highly lustrous and handsome polish; but on account of excessive hardness it is very difficult to dress.

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The plant consists of a switch about three miles long, which connects the quarries with the Iron Mountain & Southern railway, a locomotive and two stationary engines, two steam travelers, a vertical and lathe polisher, several derricks, steam drills, an office, a store, extensive sheds, work-shops, etc.

The product from 1882 to 1890 was about 250,000 cubic feet of dimension stone, about 5,000,000 paving blocks and a large amount of "rip-rap," which has been used for ballast by the Iron Mountain & Southern railway, and also extensively in the manufacture of granitoid pavement and sidewalk flags.

Among the important structures for which these quarries have supplied stone are the following:

Fagin building.....St. Louis	Rialto building.....Chicago, Ill.
Odd-Fellows' hall..... "	Northwestern Guarantee Loan Co. building.....Minneapolis, Minn.
Mercantile Library..... "	Society for Savings building..... Cleveland, Ohio.
Roe building. ..... "	Central Savings Bank...Baltimore, Md.
Singer building..... "	Union depot.....Indianapolis, Ind.
Commercial building. ..... "	City hall.....Cincinnati, Ohio
Liggett & Myers building..... "	Cincinnati Art museum. " "
Rosenheim building..... "	Ætna bank..... " "
Meyer Bros. building..... "	German Savings bank... " "
Drummond tobacco factory.... "	Whitney Nat. bank.....New Orleans, La.
Merchants' bridge..... "	Morris building.....New Orleans, La.
St. Louis stand-pipe tower.... "	Oriental hotel.....Dallas, Texas
Boatmen's Bank building..... "	Paxton building.....Omaha, Neb.
Rookery building.....Chicago, Ill.	Heest building.....Kansas City, Mo.
Marshall Field building.... "	Corrigan building..... " "
Studebaker building..... "	
Savoy hotel.....Dubuque, Iowa	

Among the largest pieces of dimension stone which have been quarried here are: The Allen monument in Pittsfield, Mass., which is 42 ft. high and 4½ ft. square at the base, and weighs about 45 tons; the columns in front of the Studebaker building in Chicago, which are ten in number, and are each 18 feet high and 4½ feet in diameter, and weigh about 18 tons; and the window sills in a Chicago building on Adams street, between 5th Avenue and Franklin street, which are each 3 feet square by 17 feet 4 inches long.

H. A. Sheahan.—In township 34 N., 3 E., a little south of the Syenite Granite company's quarry, Mr. Sheahan opened a small quarry in August, 1889. The manner of occurrence of the rock, with reference to quarrying, and the character of the stone, is similar to that of the Graniteville quarries. Little work has been done here. No dimension stone has as yet been quarried, and only a few thousand paving blocks have been produced, which were hauled in wagons to Middlebrook for shipment.

Phil. Schneider.—In township 34 N., 3 E., section 10, west half, Mr. Schneider has two granite quarries, which were opened in 1885. They are situated on the slope of a granite ridge where drainage by siphons is possible, and quarrying is easily carried on. The characteristics of the out-crop and of the stone are about the same as those of Graniteville, which have been described above. The plant consists of two stationary engines, a steam traveler, six derricks, three polishers (lathe, vertical and pendulum), a short tramway, blacksmith's shop, office, boarding house, sheds, tools, etc. A railway connection three miles long with the St. Louis, Iron Mountain & Southern railway has been made. The total output to 1890 is about six million paving blocks, in addition to an undetermined amount of dimension stone. Among the important structures for which it has furnished granite are the Lemp building and the Moline and Merchants' bridges, all of St. Louis.

Ozark Mountain.—About a quarter of a mile south of Graniteville is a quarry which was opened in 1869, and which is the oldest granite quarry in Missouri. It is in the same out-crop as the Graniteville quarry, and the stone answers to the same description. The quarry is not now worked, but when in operation, from five to six hundred men have been employed here at one time. Stone from this quarry was used in the construction of the famous Eads bridge across the Mississippi, of the Illinois and Iowa state-houses, of the St. Louis and Cincinnati custom-houses, and of the Memphis and Little Rock postoffices. The stone taken out was, however, inferior to what can be obtained, as it was mostly surface rock.

Pilot Knob Company.—In township 34 N., 3 E., section 22, center of southern half, there is a very small quarry belonging to the Pilot Knob company, from which a few paving blocks have been quarried. The out-crop of granite is very large here, and it can probably be quarried advantageously for dimension stone, as the joint-planes seem to be so situated as to facilitate quarrying, and yet not to interfere with the production of large blocks. The stone is composed of grains of clear transparent quartz and of crystals of dark pink feldspar, which latter gives it a reddish color. It takes an excellent polish.

THE LIMESTONES.

Limestones exist in these counties in inexhaustible supplies. They are as a rule easily quarried, and some of them dress very readily.

Their best color is a soft buff, although they are also of a dark gray and an almost white color. They seem to be very durable. No attempt has been made to quarry them for any commercial purposes. Locally they are used extensively for foundation bridges, walls, tiling, etc., and a few very handsome dwelling houses have been constructed of them.

Cartey and Mann.—In township 33 N., 3 E., section 1, near the center, are several small quarries in the magnesian limestone, which is here covered by about a foot of stripping. The color of the stone is blue in some strata and yellow in others. The yellow variety dresses easily and makes a handsome building stone, but the blue is less easily worked and is less valuable. The strata vary in thickness from 6 inches to 2 feet. The output from these quarries has been small, and has been used mostly for foundations. They furnished stone for one small dwelling house and for Dr. Goulding's hospital, both at Ironton, the latter a handsome edifice.

Hastings.—In township 33 N., 4 E., section 5, southeast quarter, is a small quarry in the magnesian limestone. It is situated on the west slope of a hill, where the workable stone is covered with a bed of stripping many feet thick. The color of the stone when fresh is a dark green, which fades to a gray as the stone dries. It is easily dressed and occurs in strata about two feet thick, two or more of which are workable. The output is small and has been used mostly for foundations.

Hollman Bros.—In township 33 N., 3 E., section 27, near Hogan, is a quarry in the magnesian limestone, about 70 feet long, 33 feet wide and 10 feet deep. It is on a hill-side, and is connected with the Iron Mountain & Southern railway by a short switch. The stone occurs in strata, varying from 1 to 14 inches in thickness. Its color is bluish, streaked here and there with drab or yellow. It does not dress easily. The output has been used entirely by the Iron Mountain & Southern railway, in the construction of bridge abutments and culverts.

Russell.—In township 33 N., 4 E., section 5, northeast quarter, is a small quarry in the magnesian limestone. The bed-rock is covered with about 3 feet of stripping of light-red loam. Joint-planes seem too numerous to permit the quarrying of blocks of desirable sizes for dimension work. The colors of the stone are gray and yellow, and black in the case of one non-continous stratum of marble, which has a maximum thickness of 6 inches. The stone is very tough, has numerour veins of calc-spar, and hence, is dressed with difficulty. The product has been used in Ironton and Arcadia for foundation purposes.

THE MARBLES.

In Iron county, the distribution of the marbles is confined to the territory drained by Marble creek and the head-waters of Stout's creek. No well-directed effort has been made to develop these marbles, but several partially successful attempts have been made. The chief reasons for their discontinuance have been: the distance from railways, thinness of strata, frequent seams and blotches of green and brown ferruginous clays, which weather out on exposure, and a tendency of the stone to "pluck" in a damaging way under the tools of the stone-cutter. In spite of these numerous drawbacks, there are, however, places where well-conducted quarrying might be profitable.

Sarah P. Childers.—In township 34 N., 3 E., section 35, southwest quarter, are two or three very small openings in the out-cropping marble, which were made many years ago, and are not now worked. The marble occurs in a hill which occupies an area of many acres. The hill slope is covered mostly by a thick mantle of residuary products and detrital matter; but at several horizons marble beds crop out, and it is probable that they have a total thickness of many feet. Individual strata 18 inches thick were observed. The stone has a gray color, and is mottled and streaked with green and yellow. Some of the mantel-pieces in the Capitol at Washington are said to have been taken from beds here exposed.

The exposure of marble on the Kramel land, described on page 30 of this report, closely adjoins the last, and is apparently similar in character and mode of occurrence. In addition to these localities Mr. Haworth describes the following:

About a mile up the creek from the Childers quarry, at the Dennis Reagan place, lining the north bank of the creek for a few hundred yards, are three or four layers of marble, one above the other in limestone order. A large porphyry hill stands near by to the north, so that the marble cannot be very extensive. Fragments of porphyry frequently occur in the marble and other impurities are common, so that but little can be hoped for from this place.

A second place is on one of the upper tributaries of Marble creek, along the boundary between sections 19 and 30, in township 33 N., 4 E. Here is a very white marble, but its extent could not well be determined. Probably it covers only a few hundred yards square, but

possibly it is more. A little work has been done at two points, neither of which was extensive enough to show much more than can be seen on the surface.

THE SANDSTONES AND CONGLOMERATES.

The sandstones of this region are often saccharoidal, and are mostly stained yellow or red with ferric oxide. They disintegrate most easily and are unfit for building material, although they have been used by the railway company in constructing bridge abutments, and, locally, for door and window-sills.

Several varieties of conglomerate and breccia are found, most of which are not now in their proper geological horizon, but exist only as boulders scattered over the hill slopes. The contained pebbles are mostly limestone, while the cementing material varies, being in different localities, lime, silica, and limonite respectively. On Pilot knob and Shepherd mountain there occurs a porphyry conglomerate in which the pebbles (often large enough to be called boulders) are porphyry, as is also the cementing matrix. This rock was quarried locally at Ironton, but was found to be not durable, disintegrating very rapidly.

Shepherd Mountain.—On the southern slope of Shepherd mountain is a small quarry in a porphyry conglomerate which grades into a coarse sandstone. From 2 to 10 feet of stripping of clay and boulders covers the rock. The stone is easily quarried and dressed, but that from this locality disintegrates very rapidly on exposure to the weather, and is practically worthless for building purposes. The output, which has been very small, has gone to Ironton to be used for foundations. Some of the steps of the Iron county court-house are of this stone and these are very deeply worn, compared with those of limestone with which they are associated. This is the same quarry as is described on page 3 of this report.

Sandstones of similar character have been quarried near Iron Mountain, and are referred to on pages 42 and 43; also between Pilot Knob and Middlebrook, as stated on page 31.

THE CLAYS AND SANDS.

In the area here discussed no sedimentary clays have been observed excepting such as have resulted from local washings from the hill-sides; but of residual clays there are very extensive beds, pro-

ducts from local decomposition of the rocks, which vary in thickness from a few inches to 70 feet or more.[1]

No deposits of kaolin or of other exceptionally valuable clays are known to exist, the prevalent material being only adapted to the manufacture of ordinary brick or drain tile. The only demand for bricks is the local one, which is extremely small; consequently the industry has been carried on only in a desultory way. The material used is a clay residuary from magnesian limestone, but it is fit for use only to a depth of about 18 inches, where, having been weathered and leached by rain-water, it is in a condition to make a fair quality of brick which burn to very dark colors. The clay is sticky and much sand is required in moulding it, which is probably the reason for the failure of several brick-making machines which have been tried in Iron and Madison counties.

In Iron county, brick has been made at Ironton, Iron Mountain, Middlebrook and Arcadia. The total product amounts probably to not over 6,000,000 bricks.

Sands are found in abundance along the many water-courses where they are very accessible. They are of value for building purposes, and also as road material. The friable sandstones as exposed at the described localities are also good sources of sand.

THE LEAD ORES.[2]

As already referred to on page 54, lead ore is mined at Doe Run in the northeastern corner of the sheet, but will receive notice in the report on the Mine LaMotte sheet. Diamond drill holes put down in the Belleview valley, near Graniteville and near Ironton, have failed to reveal the presence of ore bodies, so far as the writer has been able to ascertain. Thus, though the limestones of the Belleview and Arcadia valleys belong to the same formation as those at Doe Run, they are not generally ore-bearing, and the results of examinations so far are adverse to the existence of workable ore-bodies here or elsewhere within the limits of the sheet.

1 See Geol. Sur. of Mo. 1873, p. 13. Raphael Pumpelly.

2 By Arthur Winslow.

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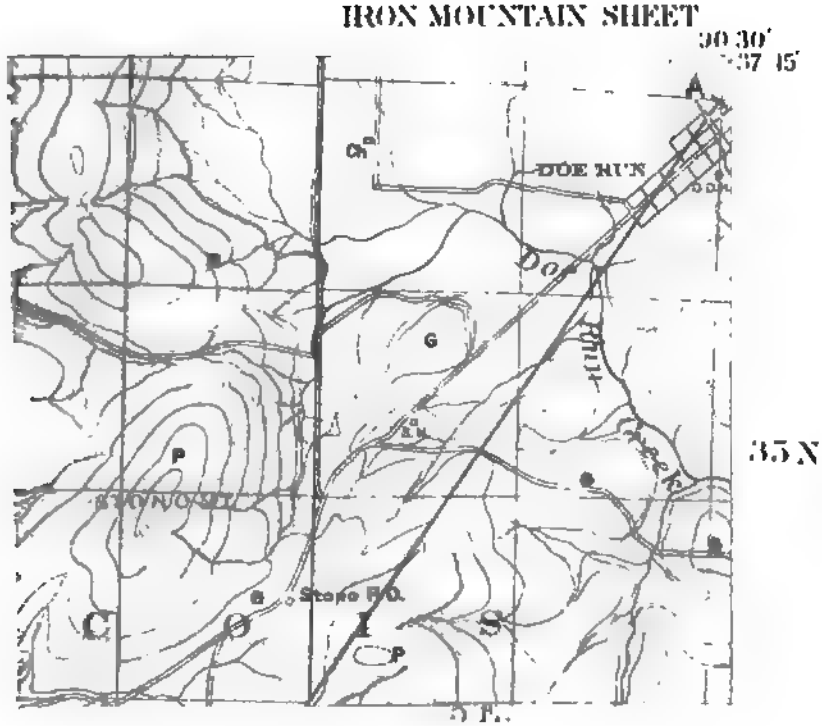
IRON MOUNTAIN SHEET



CONVENTIONAL MARKS

S	Shaft		Geological Boundary	S.H	School House
✦ D.H	Churn Drill Hole		Horizon Line	Sh	Shale
◆ D.D.H.	Diamond Drill Hole	▫	Building	S.S.	Sandstone
○	Open Well	Ch	Church	L.S.	Limestone

MISSOURI GEOLOGICAL SURVEY.

CHARLES R. KEYES, STATE GEOLOGIST.

SHEET REPORT No. 4.

A REPORT ON

MINE LA MOTTE SHEET

INCLUDING PORTIONS OF

Madison, St. Francois and Ste. Genevieve Counties

BY

CHARLES ROLLIN KEYES,
STATE GEOLOGIST.

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GEOLOGY OF THE MINE LA MOTTE SHEET.

BY CHARLES ROLLIN KEYES.

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INTRODUCTION.

LOCATION AND AREA.

The Mine la Motte sheet (plate i) is called after the oldest mining camp in the area. The latitude of the south line of the district is 37° 30′; and of the north 37° 45′; the lines of longitude west of Greenwich are 90° 15′ and 90° 30′. The sheet lies in the southeastern quarter of the state. Its southern limit is about seventy miles north of the Arkansas line and its eastern edge extends within twenty miles of the Mississippi river. It includes portions of the three counties, Ste. Genevieve, Madison and St. Francois. The position with reference to the counties is shown in the accompanying diagram (figure 1):

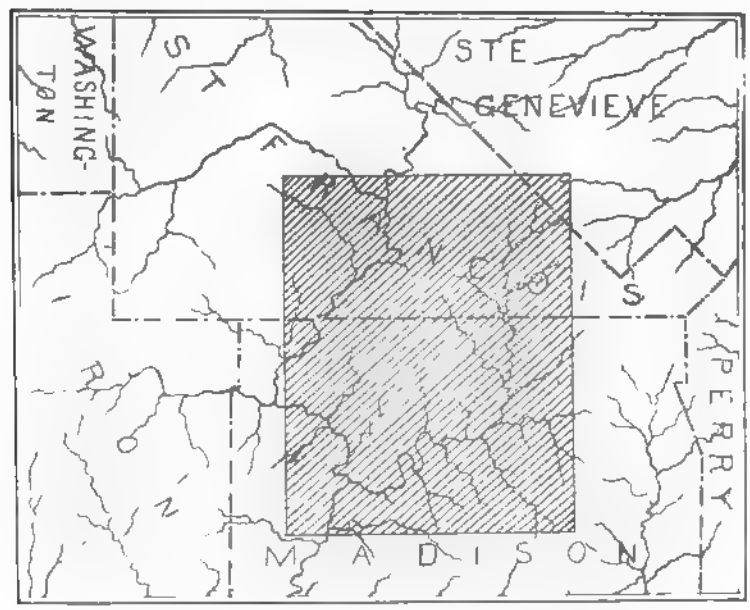
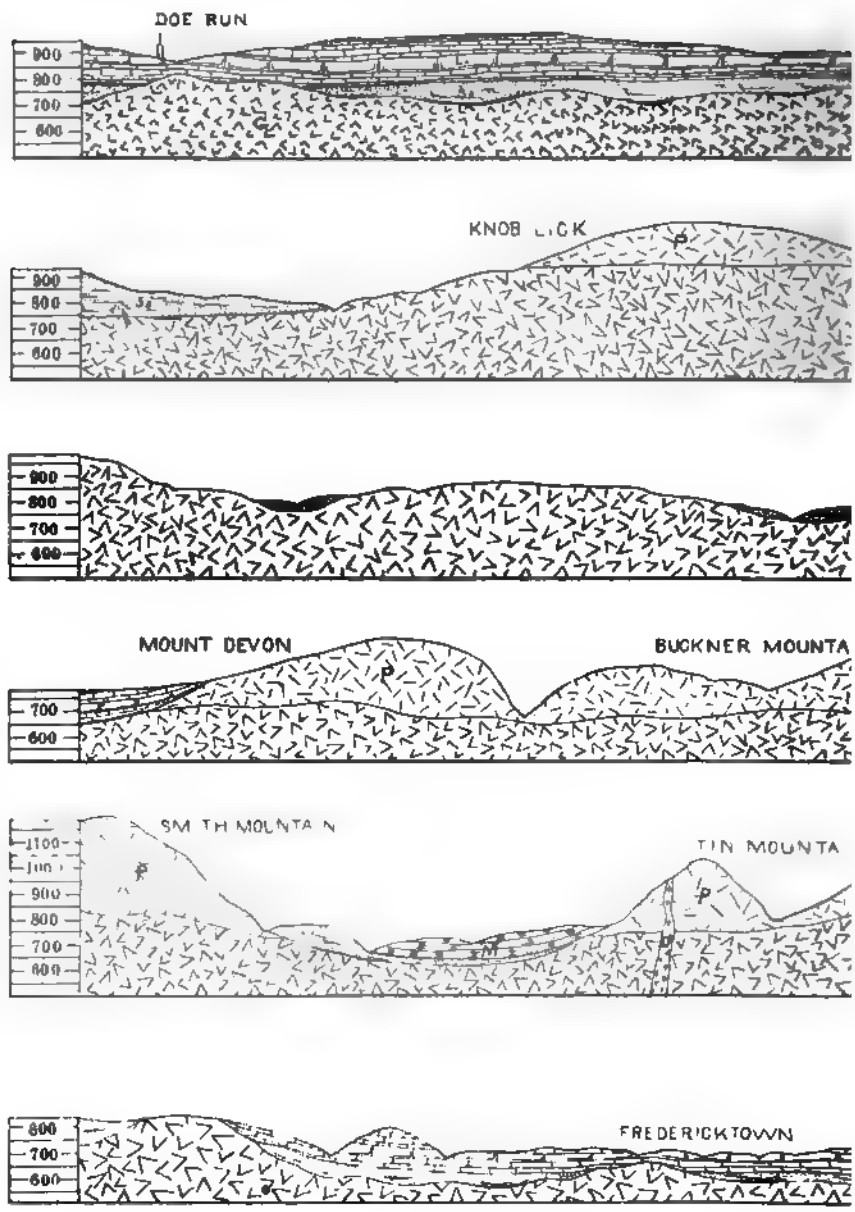


FIGURE 1. Position of the Mine la Motte Sheet.

The areal extent is 235 square miles, of which approximately three-fifths lie in Madison county and two-fifths in St. Francois. Only about two and one-half square miles are contained in Ste. Genevieve county.


DOE RUN
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KNOB LICK
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MOUNT DEVON
BUCKNER MOUNTA
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SMITH MOUNTAIN
TIN MOUNTA
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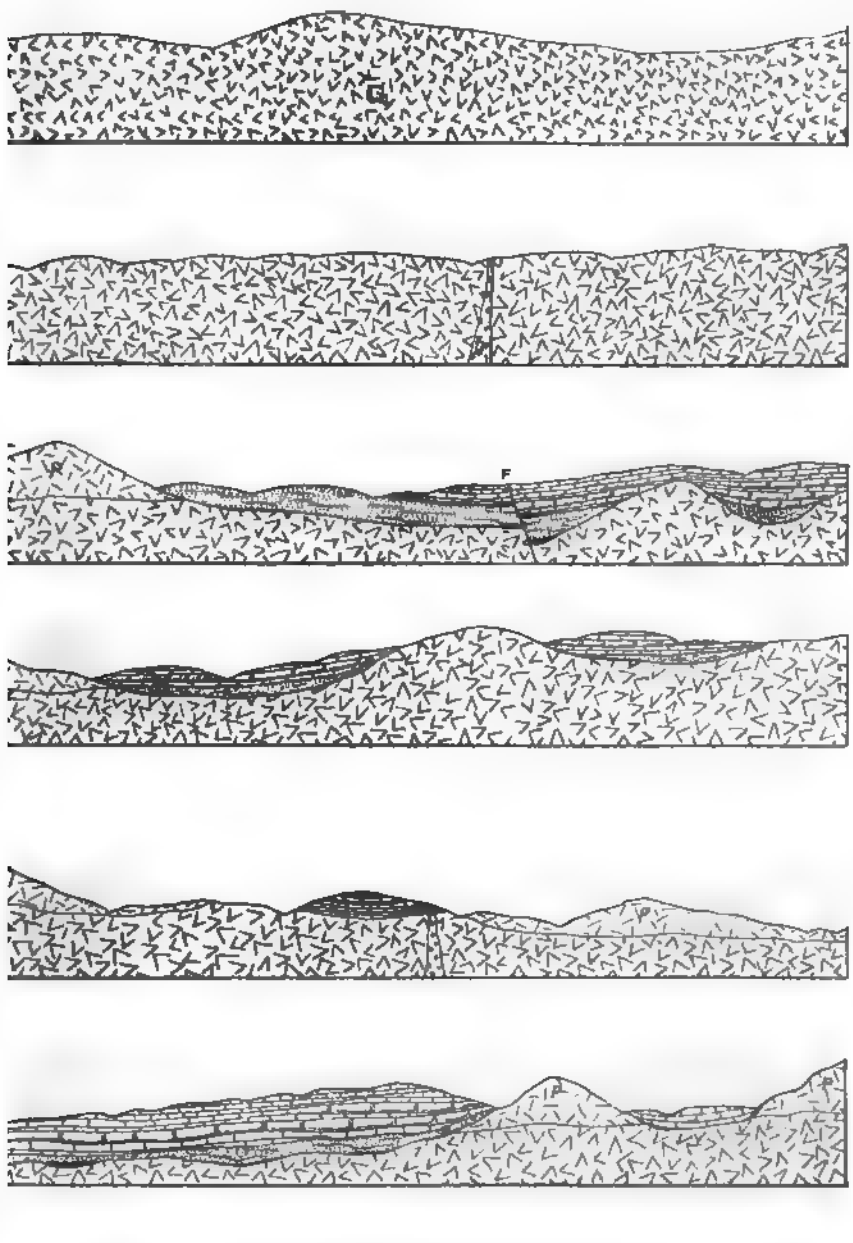
FREDERICKTOWN



ONS.

PREVIOUS WORK IN THE AREA.

The region covered by the Mine la Motte sheet has long been famous for its mineral resources. It contains the earliest discovered deposits within the limits of the state. The first lead mining in the Mississippi valley was carried on in the district now under consideration. Even before the advent of the French the Chickasaw Indians are reported as having obtained the metal in this part of the country. About the year 1720 the French explorers first found the lead deposits, and since that time mining has gone on more or less continuously.

The geological exploration of the region is, however, of very much more recent date. The first investigations undertaken to definitely make out the geological formations represented are those by King* who constructed a cross-section from St. Louis to Iron mountain; and although the Mine la Motte area was not entered the existence in the neighborhood of Archaean and Silurian rocks was recorded.

Swallow† only incidentally alluded to the rocks of the area.

Broadhead,‡ in his account of the geology of Madison county, described a considerable portion of the southern part of the area included by the sheet; and this was the most important source of information until the inauguration of the recent inquiry.

In his description of the Mine la Motte estate, Mills§ has given many details of interest.

The stratigraphical chapter in the report on the paleontology of Missouri contains the observations of Keyes|| on the relations of the Ozark series of magnesian limestones to the Archæan porphyries. The data given were obtained from near Fredericktown.

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*Proc. Am As. Ad. Sci., Vol. V, 182-200, 1851.

†Geol. Sur. Missouri, 1st and 2nd Ann. Repts., 1855.

‡Geol. Sur. Missouri, I, 342-379, 1874.

§Geological Report on Mine la Motte estate, the property of Hon. Rowland Hazard, situated in St. Francois and Madison counties, Missouri. New York, 1877

||Missouri Geol. Sur., IV, 35-37, 1894.

In the report on the lead and zinc deposits of the State, Winslow and Robertson* have recorded the facts bearing upon the occurrence of lead and, also have referred to the geological features.

Finally, Haworth† has described the crystalline rocks of southeast Missouri, some of the most important observations having been made within the limits of the Mine la Motte sheet.

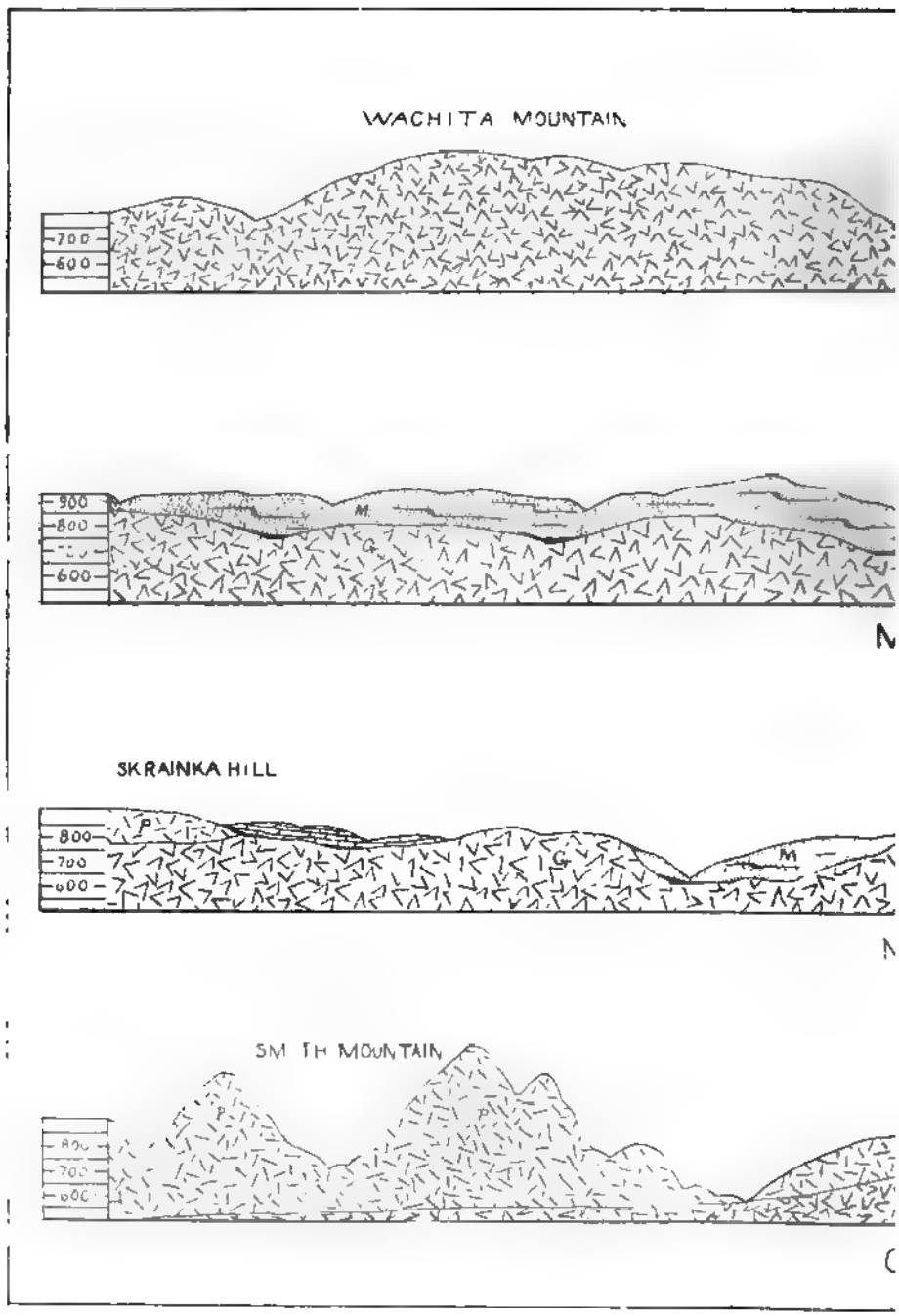
PHYSIOGRAPHY.

SURFACE RELIEF.

Main Characteristics. The Mine la Motte lies on the southern slope of the Ozark dome near the crest of the elevation. It is a semi-alpine region, with prominent, solitary peaks irregularly arranged, rather than arrayed in ranges and ridges. The extremes of altitude are about 540 and 1400 feet above tide-level. The general elevation is in the neighborhood of 1000 feet. Areas of equal altitude for every 200 feet are displayed on the accompanying diagram, figure 2.

In general two principal types of topography are represented. One is a very much broken or hilly region; the other is a broad plain with rather rough, rolling surface. The first of these comprises the porphyry peaks of the southwestern part of the district. (See plate iv). The elevations are in reality only the eastern members and outlying spurs of the St. Francois mountains, a group of more or less rugged hills which stretch away to the southwest in an interminable succession of peaks of nearly uniform height. There is no systematic arrangement discernible in these prominent surface features. Although indistinctly defined ridges may be sometimes made out, the rule is insolated mounds, large and small, rising irregularly behind one another. The landscape presents numbers of the more important ones, all about of equal height, equally distant from one another and surrounded by smaller hills. As in other parts of the region, the granite or porphyry peaks stand out in marked contrast above the surrounding plain.

*Missouri Geol. Sur., VII, 646-676, 1895.
†Missouri Geol. Sur., VIII, 81-224, 1895.


WACHITA MOUNTAIN
700
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SKRAINKA HILL
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SMITH MOUNTAIN
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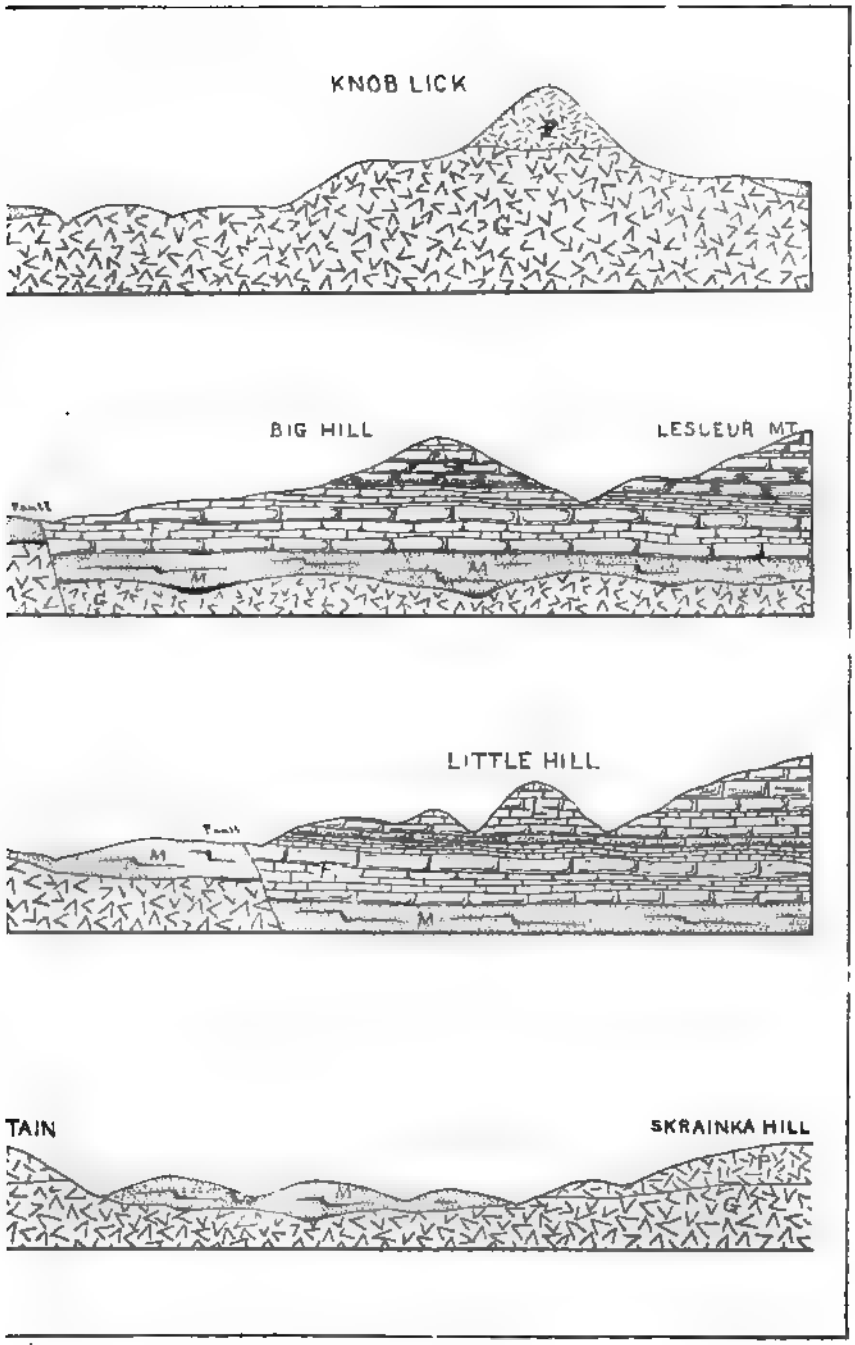
KNOB LICK
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G
BIG HILL
LESLEUR MT.
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LITTLE HILL
M
M
TAIN
SKRAINKA HILL
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P
G

Owing to the resistant character of the crystallines to the elements disintegration goes on much more slowly than with the sedimentaries; and the porphyries are less effected than the

FIGURE 2 Hypsometric diagram of the Mine la Motte sheet

granites. Hence the slopes of the porphyry hills are much steeper than any of the others. Along the streams where the waters impinge against the banks perpendicular walls are often

formed which rise to a height of 200 or 300 feet before the surface of the mounds assumes the normal slant.

Being beyond the limits of glaciation the inequalities of the indurated rock surface have not been softened or modified by accumulations of extra-limital detritus, and ice debris has in no way altered or obscured the topographical expression.

A large part of the area is occupied by a lowland plain. The margin of an upland which is much better developed farther westward passes through southwestern corner. In the northwest and northeast corners are remains of the same constructional surface which is also well displayed to the east and north of the sheet. The remnants of the old upland are all that is left of the original Tertiary peneplain which forms the general surface of the Ozark dome.

The present topographic expression is the product of two cycles of erosion. The evidences of the earlier of these are now nearly obliterated by the vigorous action of the later.

The leading features of the area indicate with great clearness both the comparative resistance of the various rocks and the geological structure of the region. The stratified rocks dip rapidly to the northeast, away from the igneous masses which lie in the southwestern corner of the district, with little faulting and no marked folding. The drainage is in a direction opposite to that of the dip except in a few limited places, where it is nearly along the strike. The highest rocks, geologically, are in the northeastern portion of the sheet, the lowest in the southwestern.

All of the rocks of the area are hard and resistant, but as compared with one another marked differences are found in their capacities for resisting disintegration and corrasion. With the vigorous erosion which has lately been renewed the effects of the varying hardness of the several rock masses greatly intensifies the contrasts of the relief. Hence the areas occupied by porphyry, granite, cherty limestone, ordinary limerock and sandstone all differ in their topographic physiognomy. But the several types may be readily grouped into two principal phases, of which one forms an upland and the other

THE HIGHLAND DISTRICT—MATTHEWS MOUNTAIN

a lowland plain. The first is the deeply incised constructional surface—the Tertiary peneplain; and the second is a moderately dissected plain lying at a somewhat lower level. It has been called the Farmington lowland. The positions of the physiographic areas are shown in the following stereogram (figure 3); the cross-sections of the district in various directions are represented on the accompanying plates ii and iii.

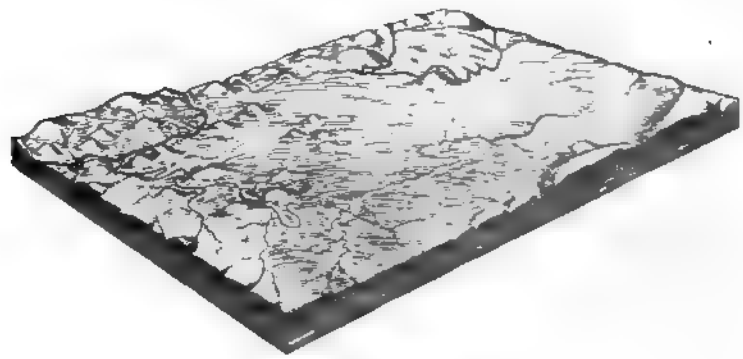


Figure 3. Physiographic subdivisions of the Mine la Motte area.

Tertiary Peneplain. The most prominent physiographic feature of Missouri is the great Tertiary peneplain which forms the general surface of the Ozark uplift. All of the present topographic expression of the southern part of the State, varied as it is, is but the effects of erosion in the effort to again reduce the region to base-level. In no part of the uplift, unless it be in the St. Francois district, does any portion of the pre-Tertiary surface project above the broad constructional plain; and even here the nearly uniform height to which the numberless peaks rise would indicate that they also were practically obliterated in Tertiary time as prominent surface features.

Within the boundaries of the Mine la Motte district the remnants of the peneplain which constitutes the uplands are found only in the southern or rather southwestern part, and in the northeastern corner. The latter is separated from the southwestern upland by a broad expanse of lowland. These areas of upland possess rugged relief, particularly the south-

western (plate iv). The northern district forms a part of the drainage divide which separates the waters which flow northeastward directly into the Mississippi river from those which flow southward into the St. Francois.

The foundations of the upland are the hardest rocks; in the southwest the porphyries and in the other parts cherty limestones. This region is deeply cut up by the streams, the principal one being the St. Francois river, which traverses the area in a general north to south direction. The tributaries are small, numerous, torrential. The valleys are contracted, steep, and the floodplains very narrow. The porphyry hills rise in high, irregularly rounded mounds, with precipitous slopes. When the watercourses wash their bases or cut across them narrow gorges are formed often with perpendicular walls.

The persistent strength of the other portion of the upland surface, in the northeast, is a hard, very cherty limestone which overlies softer, less silicious beds of limerock. Beyond the limits of the district the upland is continuous, and the portions appearing within the boundaries are long lobes or extensions which project out from main body. These ridge-like elevations terminate abruptly in steep slopes which form sections of a rather pronounced escarpment, of tortuous course, but which has a general trend of northwest and southeast. The sides of the declivity present sharply incised or crenulated outlines. The hills formed are thickly covered by the hard cherty fragments, which obscure or totally hide the strata underlying. Several prominent chert-covered hills which occupy isolated positions beyond the boundaries of the escarpment appear to be remnants of the steep slope at a time when it extended out into the lowland much further than at present. These solitary mounds often present a striking contrast to the surrounding country, and form conspicuous features of the local landscape.

Farmington Lowland. The median plain which occupies a large portion of the district is a part of a broad zone that extends over a much more extensive area. Within the limits of the sheet this belt runs in a direction nearly northwest and southeast. It includes most of the northeastern two-thirds of

the sheet. It is limited on the east by the irregular cherty escarpment of the upland forming the divide between the Mississippi and St. Francois rivers. On the west the porphyry hills interrupt its continuity.

The general elevation of the plain is about 1000 feet above mean tide. This level is 800 to 900 feet below the level of the great peneplain.

The rocks of the Farmington plain are soft, or at least much more easily succumb to meteoric influences than do the porphyries and the cherts. Its principal features are the outcome of rather vigorous erosive action upon limestones and sandstones, and its general surface is rolling. Wherever the calcareous beds predominate the topographic outlines are rounded and greatly softened; where sandstones occur the relief is bolder. In the lowland the river valleys have a tendency towards a broad open type, in contradistinction to those of the upland where the narrow contracted gorges prevail. The extent of the plain, however, is not confined to the areas of limestone and sandstone, but with some modifications covers also the granites. The latter disintegrating much more readily than the porphyries leave the areas occupied by the fine grained rocks standing far above them. The surface relief of the granite district is noticeable more rugged than that of the sedimentary areas, but the comparative resistance of the two kinds of rock are not so diverse but that the areas occupied may be grouped together.

The lowland is a plain of denudation. It is the product of a former cycle whose work was interrupted before completion. In point of time this cycle was a later one than that represented by the Tertiary peneplain, and immediately preceded the present one. The effects of the present cycle of erosion are well shown in the sharply cut trenches in the plain where erosion has recently been accelerated with vigor.

Special Features.—The Mine la Motte district exhibits with exceptional clearness certain physiographic features of great interest. These are superposed waterways; and the particular phenomena they present are so conspicuous that they have at-

tracted the attention of the inhabitants, who have applied to them the name of "shut-in." At the point of the "shut-in" the stream-valley which is usually quite wide and shallow, with flood-plains on both sides perhaps, abruptly contracts to a narrow gorge with steep sides. The watercourse continues to flow in the deep cut for some distance, when the valley rapidly widens out again to its former dimensions, and assumes the same type of relief that it had above the "shut-in."

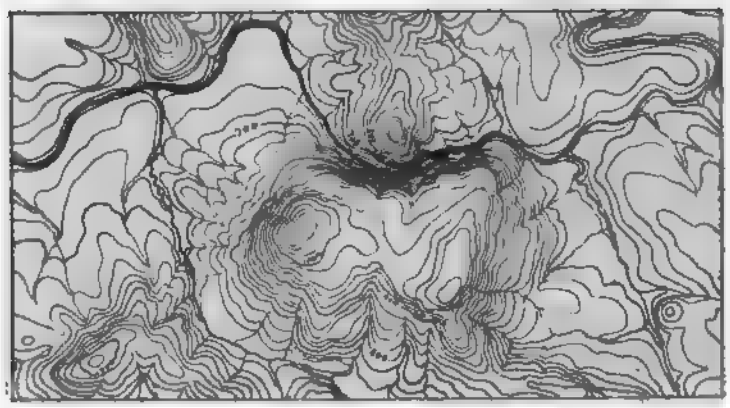


FIGURE 4 The Fredericktown Shut-in.

An examination of the lithological characters of the banks of the river shows that both above and below the point of the "shut-in" the rocks are very much softer and much less resistant than at the contracted place, being sandstone or limestone, while at the gorge the hard porphyry appears. The "shut-in" is thus a point where a stream which has been flowing over relatively soft rocks crosses a belt of very hard material. One of the best examples of a "shut-in" shown in the Mine la Motte area is on the Little St. Francois river about two miles west of Fredericktown. The stream as it enters from the limestone district into the porphyry passes between two high hills, the channel being at the bottom of a very sharp V-shaped gorge, the sides of which are the steep-sloped mountains Devon and Buckner. The watercourse continues for a distance of more than a mile through the canyon before it again emerges into its broad valley composed of limestone.

In the annexed sketch the features of the "shut-in" are admirably brought out. The rugged topography of the porphyry area with the river bisecting it is strongly contrasted with the flatter relief of the less resistant limestone areas. Even the subordinate tributaries of Slater and Mill creeks have wide valleys compared with the "shut-in." (Figure 4).

Five miles farther to the west the same stream enters another porphyry area. A "shut-in" is formed in which the river runs for a distance of more than two miles to its mouth, where it opens into a similar gorge of the St. Francois. Pine mountain rises on one side, and Tin and Hawkin peaks on the other.

The "shut-in" on the St. Francois river at the mouth of the Little St. Francois is about one and one-half miles long, and runs at right angles to the other one just mentioned. Upstream are the less resistent granites, and downstream the softer sandstones and limestones.

Similar physiographic features exist just outside the limits of the sheet in the Iron mountain district. The "shut-in" on Stout creek, two miles east of Arcadia, is one of the most notable.

The explanation of the "shut-in" is found in the rivers being superposed streams, whose courses were inherited from a former cycle. As the work of erosion was begun after the uprising of the Tertiary peneplain, the streams corraded their channels rapidly along the courses which they first assumed. In the wearing away of the rocks, of the limestones and sandstones, the old porphyry knobs were finally uncovered, and the streams encountering these cut directly across them. In order to maintain their grades they eroded deep, narrow channels in the same period that in the softer rocks wide valleys were formed.

DRAINAGE.

The general drainage of the Mine la Motte region is southerly in direction. Two streams, the St. Francois and the Little St. Francois rivers, are the principal waterways. They unite near the southwestern corner of the sheet. Only a very small

area, in the extreme northeastern corner, does not belong to the principal or St. Francois drainage system.

The St. Francois river rises a short distance north of the limits of the sheet, and flows south in an irregular, tortuous course through the western third of the area. For the most part the valley is narrow with steep sides and no flood-plains. In the upper portion of its course it is broader, more open, with flood-plains of considerable importance. This part of the channel is in the less resistant limestones, and is nearly down to grade. The decline is not more than four or five feet to the mile. Elsewhere the stream is acting vigorously upon the rocks, cutting them down rapidly. The slope of the bed is 20 to 30 feet to the mile. In the more contracted places the descent is very much more, producing rapids and falls. The principal tributaries are Doe Run, Wachita, Wolf, Turkey and Pine creeks. All are small streams; the first being about eight miles in length, and the last three not more than four or five miles long.

The Little St. Francois drains over one-half of the area. It rises in the northeastern part of the district near Libertyville, flows southward to Fredericktown and then abruptly bends, running nearly due west to its juncture with the larger stream in the southwest. Most of its course is in the less resistant limestones and the valley is consequently open. Only at its mouth and near Fredericktown is it contracted to a narrow gorge. Directly east of Knob Kick the river traverses the eastern edge of a sandstone belt for several miles; and the west banks are very steep, but on the opposite side where the limestones prevail the slope is gradual. The chief creeks flowing into the Little St. Francois are Wills, Musco and Fritzzell on the west, and Rock, Village, Mill, Slater, Matthew and Cedar on the east and south.

STRATIGRAPHY.

GENERAL GEOLOGY OF THE REGION.

The district covered by the Mine la Motte sheet contains the oldest rocks of not only Missouri, but of the whole Mis-

sissippi basin. It forms a fifth part of a larger area made up of similar rocks. Around the nucleus of ancient crystallines the strata of subsequently deposited formations are grouped in concentric belts of greater or less breadth. The crystalline nucleus is composed almost entirely of igneous masses which include chiefly granites, porphyries and diabases. In many places an imperfect bedding is often noticeable in the porphyries and granites, which formerly gave rise to the belief that these rocks were sediments which had undergone metamorphism to such an extent that they are now in the last stages of the process. Recently it has been satisfactorily demonstrated that the apparent lines of sedimentation are really pseudo-stratification planes, and that they have been developed in a way that is wide-spread among rocks which have cooled from molten magmas.

The porphyry appears to be the surface facies of the coarse-grained granite and seems to graduate downward into the latter. This is shown in the areas where the granite has been deeply eroded, leaving high steep hills, the summits of which are often found to be capped by porphyry. This being the case the general relation of the granite to the porphyry is that the latter rests as a broad sheet upon the former. Where the flinty crust, as it were, is not broken through by erosive agencies the porphyry still remains as the surface portion of the general crystalline mass.

The continuity of the massive rocks is interrupted by numerous lines of fracture. Most of them are merely jointing planes; many are slight fault lines; while still others have the walls spread apart, the space being filled with basic material, which forms dikes, sometimes of considerable breadth.

The jointing planes form several very different series. Remarkable uniformity in direction is shown by the planes belonging to the most prominent set. Slight variations exist, but the general trend is north 60 degrees east. The second series of seams makes angles of 80 and 100 degrees with the more prominent one.

Faulting is commonly quite unimportant, the throw being usually not more than a few feet. Some notable exceptions, however, are known. The position and extent of the dislocations are more clearly defined in the stratified rocks than in the crystallines.

Dikes of basic rock occur rather abundantly. They vary from a few inches to 50 yards or more in width, and cut the granites and porphyries alike. Nowhere have they been observed to penetrate the overlying sedimentaries. Their number and wide distribution, the great weight and black color of the rock composing them and their peculiarities in weathering, causes them to attract much attention.

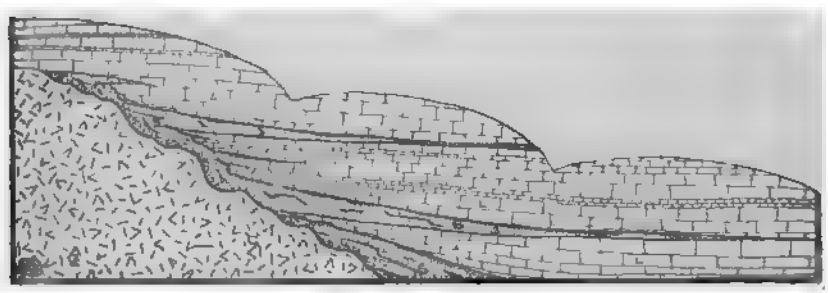


FIGURE 5. Stratigraphical Relations of the Sandstones.

The igneous masses of the region are all older than the sedimentary strata which everywhere rest uncomformably upon the acid rocks. A long period of erosion is represented by the unconformity. The evidence is abundant showing that as the sedimentary rocks were laid down over the region the diversity of surface relief was even greater than that at the present time. This very marked irregularity in the pre-Cambrian surface is the cause of many anomalous stratigraphic features which are met with throughout the region.

The sedimentary rocks are represented by an extensive succession of magnesian limestones with intercalcated sandstones. Almost always the latter cover the pre-Cambrian elevations, they also occupy positions between the calcareous beds. (An expression of these relations is given in the accompanying cut, figure 5.)

The stratified rocks dip away in all directions from the central crystalline area. Younger and younger strata successively form the surface rocks as the distance increases from the porphyry hills. The Paleozoic is well represented from the Cambrian to the Carboniferous. From Iron mountain to the nearest point on the Mississippi, a distance of thirty miles, the entire sequence from Archaean granites through the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, to the Coal Measures, is passed over.

GENERAL RELATIONS OF FORMATIONS.

In the Mine la Motte district the lithological features of the various formations are so persistant that their lithological characters become important criteria in the consideration of the rocks. Two principal classes are recognized, and these are sharply contrasted. One is composed of massive crystallines; the other of indurated clastics.

As in other parts of the southeastern portion of the State, the crystalline rocks are, with few exceptions, igneous in origin. They form a considerable series of both acidic and basic masses, the latter breaking through the former in dikes. The first mentioned constitute the granite and porphyry, and the second diabase.

The igneous rocks occupy the southwestern half of the area, and are beneath all the stratified beds. Their upper surface, as in other parts of the region, is very uneven and the sedimentary layers are irregularly disposed upon them. They are Archæan in age.

The indurated clastics embrace limestone or dolomite, marble, sandstone and shale. The sandstone forms a belt one to three miles wide, and of considerable thickness around the crystallines. There is usually a bed of coarse conglomerate at the base, which is composed of rounded boulders of the crystallines. The arenaceous beds commonly rest directly upon the igneous masses, though frequently they are interstratified with the limestones. The sandy material usually mantles the old crystalline elevations.

The limestone constitutes the surface rock on three sides of the sheet, forming a broad zone outside of the basal sandstone strip. It is for the most part dolomitic and often contains fine siliceous grit. Some is cherty, especially that in the extreme northeastern corner. As a rule, the limestone immediately overlies the sandstone, though in certain instances the latter thins out and the former rests directly upon the granite. The highly siliceous or cherty character of the uppermost beds gives rise to marked physiographic features. The calcareous layers merge downward into the arenaceous, forming an uninterrupted succession of strata.

The marbles are compact beds which lie directly upon the porphyry. Stratigraphically they are unimportant deposits.

Shale is found only in thin layers, rarely more than a few feet in thickness. Those at Mine la Motte are fossiliferous.

A general scheme of classification of the geological formations exposed within the limits of the district is shown below:

Table of Formations in Mine la Motte District.

Group.	System.	Stage.	Formations.
Cenozoic	Quaternary	Recent	Alluvium
Paleozoic	Cambrian	Upper	Lesueur limestone Fredericktown limestone LaMotte sandstone
Azoic	Archæan		Iron Mountain porphyry Knob Lick granite

TYPICAL EXPOSURES.

GENERAL SECTION.

The combined maximum thicknesses of the rocks exposed above the lowest point within the limits of the Mine la Motte area amounts to about 1400 feet. Actual vertical measurements of outcrops at any one place would, however, be considerably less. The general sequence is represented in the accompanying figure 6.

Number 1, the Knob Lick granite, is best shown, perhaps, around the base of the mountain from which the member takes its name. It occupies a considerable area to the south and

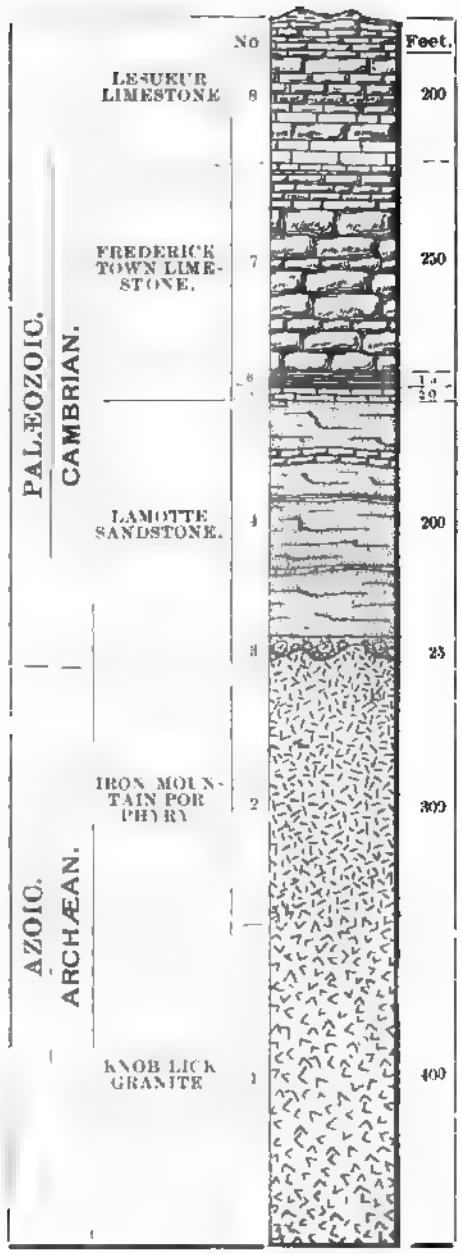


FIGURE 6. General Section of Rocks of Mine la Motte District.

west, and forms the largest single surface exposure of granite in the State. Number 2 is well shown in most of the mountains in the southwestern part of the sheet, as well as in many other places within the limits of the district. It is found occupying all the most prominent eminences. Where associated closely with the granites it is found to graduate downward into the course-grained rock. Within the large granite area already mentioned, many of the prominent peaks are capped by the porphyry, so that everywhere the latter may be regarded as the upper or surface representative of the former.

The sedimentaries rest in marked unconformity upon the crystallines. The juncture of the two is usually marked by a bed of crystalline pebbles and bowlders — number 3, which is well shown at many points. The principal arenaceous member of the succession is the LaMotte sandstone — number 4, which is finely

displayed along the railroad north of Mine la Motte station, and on the estate along Rock creek, and the Little St. Francois river; also north of Knob Lick station. The succeeding formation, comprising numbers five to seven, is well exhibited in the neighborhood of Fredericktown, especially at the railroad bridge one mile to the north. The shales in the lower part are best exposed at the mines near Mine la Motte, those of the old Rattlesnake diggings being, perhaps, most typical. The Lesueur limestone has its characteristic development around the head waters of Rock creek, though it is well shown in numerous other localities.

STANDARD SECTIONS.

The outcrops of the granite and porphyry are so similar throughout the entire vertical exposure that the sections, when both are displayed, show little beyond a gradual transition from one to the other.

One of the best exposures showing the relations of the stratified and massive rocks occurs on the Little St. Francois river, a few hundred yards below the point where the Belmont branch of the St. Louis, Iron Mountain & Southern railroad crosses that stream. The disposition of the beds is shown in figure 11.

I. Section north of Fredericktown on Little St. Francois River.

FREDERICKTOWN FORMATION.

		Feet.
5	Dolomite, buff, heavily bedded, with marly partings	80
4.	Dolomite, light reddish to white, rather heavily bedded, but becoming somewhat shaly in places at the base, siliceous, with fine quartz pebbles at the bottom	15

LA MOTTE FORMATION

3	Sandstone, massive, though cross-bedded in places, compact, calcareous above, brown in color, fine grained, shaly and argillaceous below	25
2.	Conglomerate, containing large, rounded bowlders of granite, up to two feet in diameter, with numberless smaller pebbles, sand and clay in the matrix, two to five feet	3

KNOB LICK GRANITE.

1.	Granite, red, coarse-grained, passing into porphyry, cut by basic dikes (exposed)	20

At this point only the attenuated edge of the LaMotte sandstone is shown. As exposed in many of the railroad cuts

to the north, the formation presents the same general lithological appearance, a yellowish, rather heavily bedded sandrock, with thin shaly bands sometimes separating the various beds. Its texture and general character is the same throughout, as is indicated from the diamond drill cores which have been obtained from various places. A drill-hole put down a short distance east of the blacksmith shop at Mine la Motte and near the margin where the limestone begins to overlap gave:

II. Section at Mine la Motte.

		FEET.
9.	Soil	2
8.	Clay, brown and reddish, residuary	11
7.	Limestone, whitish to gray, arenaceous	2
6.	Sandstone, variegated, and stained	10
5.	Sandstone, whitish	12
4.	Sandstone, buff to straw color	28
3.	Sandstone, light colored, white and yellow in thick alternating beds, with occasional shaly band	178
2.	Sandstone, light reddish	20
1.	Sandstone, reddish, darker than layer above (penetrated)	9

The shaly portion of the Fredericktown formation is best represented perhaps in the vicinity of Mine la Motte, though many of the exposures, which were formerly well exhibited, are now greatly obscured or hidden completely. At the Rattlesnake diggings the following minute alternations were recorded by Mr. J. E. Mills, former engineer to the mining company:

III. Section at Rattlesnake Diggings.

		FEET.
16.	Limestone, thinly bedded, and drab shale	1.34
15.	Limestone, shaly	.52
14.	Shale, clayey	.25
13.	Limestone, shaly	.17
12.	Shale	.36
11.	Limestone	.35
10	Shale	.13
9.	Limestone	.81
8.	Shale	.56
7.	Limestone	1.31
6.	Shale	.20
5.	Limestone, light drab, with reddish drab blotches	1.42
4.	Shale	.40
3.	Limestone, thinly bedded, with clay partings, lighter colored than below	.54
2.	Limestone, heavily bedded, blue and gray, with tendency to slaty structure	3.00
1.	Limestone, same as No. 2, with galena (jack bed)	7.00

The formation in general is so uniform in its lithological characters that sections taken at different horizons present very nearly the same sequence of beds. In the vicinity of Mine la Motte, the borings which are made with a diamond drill, show no marked differences. The section at shaft No. 1 at the mines is as follows:

IV. Section at Shaft No. 1 at Mine la Motte.

		Feet.
10.	Clay	13
9.	Limestone, yellowish	8
8.	Limestone, blue	16
7.	Shale	1½
6.	Limestone, blue, slaty, with galena band at base	23½
5.	Limestone, blue, with galena and pyrite	7
4.	Limestone, white	19
3.	Limestone, abounding in galena in disseminated form	7½
2.	Limestone, white, with much galena disseminated	4
1.	Limestone, white, containing some galena in different ledges	26½

One and one-half miles due east, drilling has been done for the purpose of locating a fault. On the east or down throw side the limestones, which are now removed through erosion on the west side, are represented in great thickness, showing that much of the formation in this part of the district has disappeared. The upper part probably represents a portion of the cherty limestone which lies above the typical Fredericktown beds. The lower part is manifestly the LaMotte sandstone. The total depth of this hole is 794 feet, and the diamond drill record (No. 723) is:

V. Section of Drill-Hole east of Mine la Motte.

		Feet.
30.	Clay, brown, residuary, with many chert fragments	27
29	Limestone, yellow	39
28	Limestone, dark gray	38½
27	Limestone, gray, slaty	3
26.	Limestone, dark gray	12
25.	Limestone, gray	1½
24.	Limestone, dark gray	78
23	Limestone, gray	4
22.	Limestone, dark gray	22½
21.	Limestone, gray, arenaceous	5
20	Limestone, white, arenaceous	30
19.	Limestone, white	10½
18.	Limestone, white, arenaceous	7½
17.	Limestone, gray	24

16.	Limestone, dark gray	15½
15.	Limestone, white	86
14.	Limestone, gray	6½
13.	Limestone, dark gray	4
12.	Limestone, gray	3
11.	Limestone, dark gray	45
10.	Limestone, gray	10
9	Limestone, white	2
8.	Limestone, dark gray	113
7.	Limestone	12
6.	Limestone, white, arenaceous	2
5.	Limestone, gray	8
4.	Sandstone, gray	½
3.	Sandstone, white	12
2.	Sandstone, dark gray	2
1.	Sandstone, white	8

On Rock creek, two miles northeast of the town and one half mile east of the Libertyville road, the same fault has been located and borings made. On the down-throw side the holes appear to have passed through the limestone into the sandstone below.

VI. Section north of Mine la Motte.

		FEET.
13.	Clay, reddish, with abundant chert fragments	8
12.	Limestone, yellowish, decayed more or less	5⅓
11.	Limestone, gray	106
10.	Limestone, light reddish	8
9.	Limestone, white	6
8.	Limestone, reddish	5
7.	Limestone, gray	14
6.	Limestone, dark colored	2
5.	Limestone, gray	8
4.	Limestone, white	21
3.	Limestone, dark colored	96
2.	Shale, dark colored	3
1.	Sandstone, friable, white	3

The limestone here has a thickness of 270 feet. It rises in the hills near by to a height of 40 to 50 feet above the top of the drill-hole; and to the east, within a mile, it reaches an altitude of more than 200 feet more. The chief portion above the creek level and the horizon of the drill-hole is the cherty or LeSueur limestone.

GEOLOGICAL FORMATIONS.

The general sequence and arrangement of the rocks open to inspection within the limits of the area covered by the Mine la Motte sheet may be inferred from the table of formations,

the geological column, and the different sections given. From the descriptions of the various vertical sections the principal lithological characters may be deduced. Upon the evidence set forth by these detailed statements may be based all attempts to correlate accurately the different beds in various parts of the district.

By bringing together in a connected way this seemingly more or less unrelated information, and by considering as a unit each geological formation, an aspect is given to the subject that is somewhat different than when the details are shown in the selected sections which much necessarily appear more or less isolated.

The range of formations is not great. The Archæan crystallines are not complicated masses. The indurated clastics do not present very great variation, and all belong to a single geological system—the Cambrian. No Quaternary deposits, except the residuary formations and a little alluvium, are found in the region.

ARCHÆAN.

(By C. R. Keyes and E. Haworth.)

The Archæan rocks are all igneous in origin. About one-half of the Mine la Motte area is occupied by them. In varietal types there is small range. By far the larger proportion is an acid series comprising granite and porphyry, the former making up fully nine-tenths of all the eruptives exposed within the boundaries of the sheet, and forming a part of the largest single area of granite found in the State. The basic rocks are diabases which occur in dikes cutting through the acid masses.

GRANITE

Physical Characters.—The granites which are found within the limits of the area under consideration are rather coarse-grained, very compact rocks, of a reddish to bluish color. As a rule the texture approaches the porphyritic, and the rock passes into a true granite-porphyry. Phenocrysts an inch or more in length are not infrequent in many places. On the other hand, the rock becomes fine-grained, graduating finally into typical porphyry.

In the porphyritic facies of the granite, the feldspars make up the greater part of the groundmass. The crystals have so interfered with one another during the period of their formation that they have produced a hypidiomorphic, granular mass, through which are scattered the quartz grains in the same way as in the groundmass of a quartz-porphyry. At other times the quartz crystals have formed in the spaces between the feldspar grains. They then occasionally have some of their crystallographic faces preserved, indicating that they were formed before the complete crystallization of the feldspathic material; or they occupy the irregular spaces left between the feldspar grains, showing that they were formed last.

Chemical Composition. Analyses show that the typical granites of the district do not differ materially from typical granitic masses in other parts of the world. The degree of acidity often varies between rather wide limits. A complete analysis by Melville of the typical rock from Graniteville, which is out side of the area, gave the following results:

	PER CENT.
Loss on ignition	0.52
SiO_2	77.05
Al_2O_3	11.77
Fe_2O_3	2.33
CaO	2.21
K_2O	3.98
Na_2O	2.90
P_2O_5	0.02
Total	100.68

Another partial analysis of the granite from the vicinity of the Silver mines, by the St. Louis Sampling and Testing works, gave:

	PER CENT.
SiO_2	73.98
Al_2O_3	14.32
CaO	1.04
K_2O	3.32
Na_2O	4.56
Total	97.22

Mineralogical Constitution. The granite is a mixture of quartz and feldspar as the principal components, with some biotite also as an essential ingredient. As accessory consti-

tuents there are apatite, zircon and magnetite. In order of crystallization the three minerals last mentioned are the first to form. They occur in minute crystals commonly with more or less well defined crystallographic faces. They appear as inclusions in all of the later formed minerals but most abundantly in the biotite.

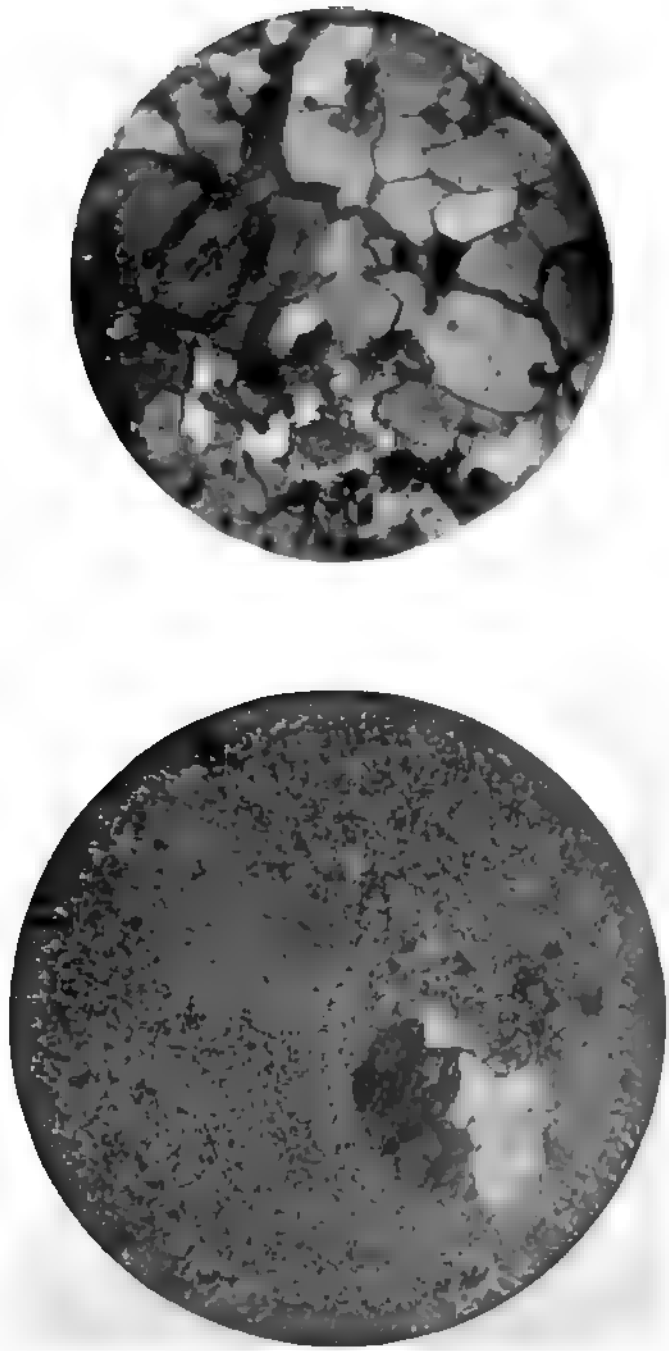
Next in order of formation are the ferro-magnesian silicates, biotite and hornblende. Both of these minerals are comparatively rare. The first mentioned forms an important constituent only in a few cases. It is unevenly distributed, so that at some points the rock containing it is quite mottled, though only a short distance away the mica is entirely absent. Further, in a locality where black mica occurs it often forms segregation masses from a few inches to a foot in size. Although apparently made up of this mineral a close examination shows the presence of quartz and occasionally a small amount of feldspar. Sometimes the segregations are so large as to cause considerable annoyance in the quarrying.

Hornblende has been observed in a few instances but very sparingly. Of all the sections of the rock examined less than half a dozen contain this mineral and then only as occasional crystals. Much of the dark colored component which is commonly called hornblende is not such, but black mica.

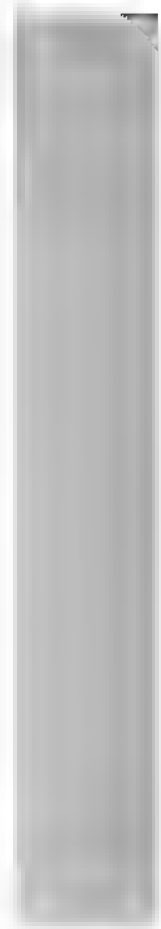
Both potash and soda feldspars are represented, the former constituting much the greater part of the rock. It is the reddish orthoclase and microcline that imparts to the granite its characteristic color. The triclinic feldspars are albite and oligoclase.

The quartz is usually allotriomorphic, with some gas bubbles and often slender hair-like needles.

Microscopical Features—The minute characters are of particular interest, and have an important bearing upon the investigation of the rock as a building stone. In thin slices, under the microscope, the granite is found to be an allotriomorphic or hypidiomorphic granular aggregate of quartz and feldspar, with some mica and the accessory constituents in minute crystals. Its general appearance is shown in the accompanying



THIN SLICES OF GRANITIC ROCKS



photomicrograph (plate v, figure 1) which is magnified 30 diameters. The fundamental differences in the appearance of the granite and the porphyry is easily made out by comparing this illustration with the other one on the same plate (figure 2).

Structurally, two varieties of the granitic rocks are represented. First, there is the perfectly granular, in which the component grains are all more or less uniform in size, and in which the different periods of crystallization are not distinguishable. This is the typical granite. Second, there is the variety in which a greater or less disparity in the dimensions of the essential constituents is observable, and in which at least two generations of crystals may be readily made out. In its best development it is the porphyritic granite. The essential difference in these two facies of structure are more clearly brought out in the annexed cuts (figures 7 and 8):

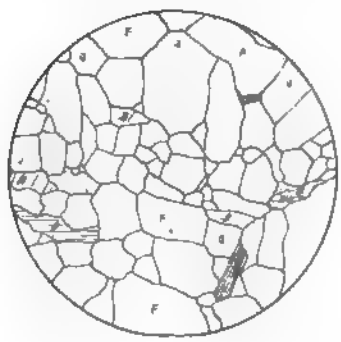


FIGURE 7. Thin slice of granite.

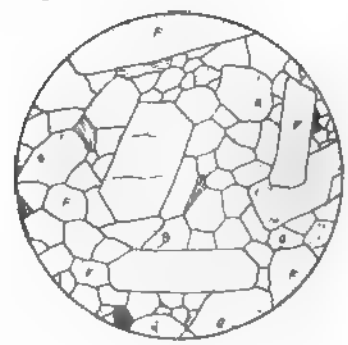


FIGURE 8. Thin slice of porphyritic granite.

The feldspars show little indications of decomposition, which is a very favorable point in determining the value of the rock for building purposes. Moreover, the absence or rarity of biotite and other ferro-magnesian compounds is another factor in showing the great resistance of the granite to atmospheric decay.

Several very interesting features are brought out through microscopical examination, which deserve passing mention. These are the occurrence of secondary enlargements of feldspar crystals which have suffered rounding through magmatic corrosion. The later feldspathic material is oriented the same

as in the inclosed core (figure 9, in which the upper and lower halves are cut at different angles). Another striking structure is the micropegmatite, the grains showing it being often very abundant (figure 10).

FIGURE 9. Secondary enlargement of feldspar

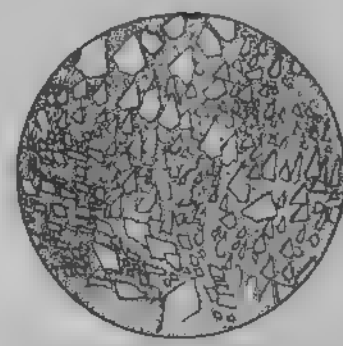


FIGURE 10. Thin section of micropegmatite

Distribution and Field Relations.—As already stated, a very large proportion of the area occupied by the crystallines of the Mine la Motte district is granite. The extent of the principal mass is equivalent to an area of nearly 50 square miles. It forms a part of the great central granite mass of the region. From Knob Lick it reaches westward beyond the limits of the sheet. Its north and south extension is from Doe Run to the Silver mines. On all sides, small, isolated areas also occur. On the north the central granite area is bounded by the St. Francois river, and on the east by paleozoic sandstones. Along the river bluff, in the vicinity of Syenite, the rock is red in color, but a short distance away it assumes a bluish tint. In some places, as south of the Milne and Gordon quarry, it appears to pass into a porphyry phase, but farther south the blue variety is found. Still further southward, at Knob Lick hill, a fine-grained rock occurs, which gradually changes into a porphyry before the summit is reached, so that the highest portion of the elevation is composed of the ordinary, red porphyry.

The genetic relations of the red and blue granites are of much interest, but the difficulties arising in attempting to trace their boundaries are great, on account of the heavy covering

of soil which exists over much of the surface between the river bluff and the steeper parts of the hill, which is about half a mile away. When the granites were first carefully observed, it seemed quite possible that they are not the same mass, but belonged to two different periods of eruption, but so far as can be observed the evidence is quite conclusive that the red granite, the blue granite and the porphyry are one in origin. In considering more carefully the distinguishing characters of the two periods, it is manifest that there is only a slight difference in the color of the feldspar. Each variety is composed essentially of quartz, feldspar and a small amount of biotite, in about the same relative proportions; and has practically the same texture.

South and west of Knob Lick hill the granite varies considerably, sometimes closely resembling porphyrys, but at others is very coarsely crystalline. Wherever a ridge or hill occurs the texture invariably becomes finer, and the rock correspondingly more like porphyry. The only important change in composition is a variation in the amount of biotite. For a few miles south of the locality just mentioned this mineral seems to be wanting. But farther to the west, especially in the vicinity of the Silver mines, and on Stout creek beyond the limits of the sheet, it is almost as abundant as around Syenite. To the northwest of Syenite the biotite is comparatively abundant for a few miles, then it gradually diminishes in quantity, and disappears altogether in the northwest part of the area.

North of the river, opposite Syenite, sandstone prevails as the surface rock, but here and there erosion has been removed is so that considerable granite crops out. Such is the exposure at the old Allen and Veith quarry on Doe Run (Tp. 34 N., R. V. E., Sec. 36). A red granite occurs quite similar to that found at Syenite; and also at the St. Louis quarry a little farther to the northeast. At the latter point the exposure is very small, the sandstone coming to the walls of the quarry. Among the small isolated areas is one on Rock creek, north of Mine la Motte, which has a very striking black and white mottled appearance, the peculiarities in the color of which is

due to an almost pure white feldspar and an intensely black biotite.

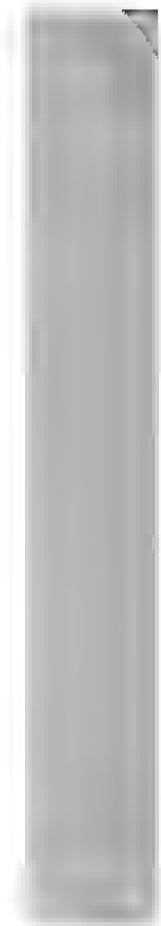
On the Mine la Motte estate, just east of the dressing works, is a small granite hill of a few acres in extent, and still farther to the east is a larger mound of the same kind of rock. These are the most easterly exposures within the limits of the sheet. Both are comparatively rich in biotite, and the feldspar is red, giving it a very pronounced red and black color. In texture it is finer than the typical granite.

East of Mine la Motte station are three low granite hills. The Little St. Francois river passes between the northern two, and the Belmont branch of the St. Louis, Iron Mountain & Southern railway between the southern two. The granite in the two

FIGURE 11. Disposition of Sedimentaries on Crystallines.

northern areas is about the same and carries a considerable amount of biotite. The rock in the southern one of the three hills has little if any biotite and is not so coarse-grained. This is the place, below the railroad bridge, where occurs the exceptionally good exposure, showing the juncture between the granite and the overlying stratified rocks. The river makes a small horse shoe curve and cuts off the southeastern portion of the granite. On each side of the curve, at points not over two hundred yards apart, the relations are well displayed (plate vi). The crystalline rock is a part of an old pre-Cambrian hill. Its surface is paved with rounded boulders of granite, from a few inches up to several feet in size. These are embedded in a compact sandstone which overlies the granite to a thickness of a dozen feet or more, becoming somewhat thinner, however, uphill. The relations are shown above (figure 11).

JUNCTURE OF CAMBRIAN AND ARCHÆAN, FREDERICKTOWN.



Immediately north of Fredericktown are a few small granite mounds. One is really in the northwest part of the village on the west bank of Saline creek. It is only a few rods in diameter. Another similar exposure is just north of the railroad station, and two others exist about one-half mile to the east. All the rock carries small amounts of biotite, has red feldspar, and is tolerably fine-grained. Two and one-half miles northwest of Fredericktown is a low granite hill (Tp. 33 N., R. VI E., Secs. 1 and 2). The surface exposure covers about forty acres. It is a coarse-grained, red and black mottled variety.

West of Fredericktown, about two miles, on the eastern side of Buckner mountain, is a long, narrow strip of granite, which lies between the porphyry, forming the hill and the limestone surrounding it. It is a red rock with a small amount of black mica. In places it is coarse-grained, but toward the west gradually passes into the porphyry. On the western side of the same elevation the porphyry often becomes sufficiently well crystalized to admit of being worked into paving blocks.

South of Fredericktown several small outcrops of granite occur. There is also apparently a ridge extending southward, which is composed of granite, but has not, as yet, been exhumed through erosion. The summit was encountered in excavating a cellar on the Calhoun place. A little farther southwest, near the river, a granite knoll occupying an area of a couple of acres is found.

Another small area of granite is found on the south side of mount Devon. On the northwestern spur of Matthews mountain (Tp. 33 N., R. VI E., Sec. 34), is an irregular mass of granite covering some 50 acres. Bowlders of decay, 20 feet in diameter, are found here. The rock is the ordinary red variety of granite. On three sides of the mass the granite gradually changes into porphyry.

The eastern base of Hawkin mountain is composed of granite. It is a narrow strip extending northwest and southeast for a distance of fully one and one half miles. At the southern end it gradually passes into porphyry. The typical rock is well crystallized, and at some points, especially near

the Wesley chapel, contains an unusually large amount of black mica. The feldspathic constituent is red, forming a red and black mottled rock.

A mile to the southwest, on a mound just beyond the extreme eastern portion of Tin mountain, is a similar mass of granite. Toward the west it changes into porphyry.

The headwaters of Cedar creek pass between two small granite hills. The easternmost occupies several acres. The other is larger and higher. The rock is a typical granite-porphyry; but in its fracture, in its weathering into immense rounded bowlders and in its general appearance, it resembles typical granite. On the eastern side of the hill it becomes eminently porphyritic.

East of Blue mountain is a prominent, very steep, rounded hill, on the southwestern flank of which is a small area of granite, of much interest on account of its isolated position in a broad field of porphyry. It is a gray variety, but with only a very small amount of black mica. In texture, it is fully as coarse-grained in the central part as the ordinary granite, but gradually becomes finer toward the margins.

PORPHYRY.

Physical Characters—The porphyries are hard flinty rocks, generally of a reddish color. The latter, however, ranges from a light pink to a dull, dark gray or purple. In texture there is considerable variation. The groundmass is dense and very fine-grained. It assumes all graduations from a coarse microgranite to a fine devitrified glass. Through the groundmass are scattered abundantly large individuals of quartz and feldspar, the phenocrysts. The fine-grained, compact character of the rock enables it to resist degredational influences in a remarkable way, as is shown by the fragments loosened in jointing, which preserve sharply all their irregularities long after the hardest granite bowlders have become perfectly rounded or entirely decayed. The rugged topographic forms presented also clearly indicate the same properties of withstanding

weathering influences. The fracture of the porphyry is splintery or subvitreous.

Chemical Composition—In the porphyries which have been analyzed there is not much variation in the acidity, rarely more than 4 per cent, the range being from 68.60 to 72.40 per cent. An analysis by Melville, of the typical porphyry, the samples of which were obtained just beyond the west boundary line of the sheet (Tp. 33 N., R. V. E., Sec. 5), gave the following results :

	PER CENT.
Loss at 100° C	0.17
Loss on ignition	0.26
SiO_2	71.88
Al_2O_3	12.88
Fe_2O_3	3.05
FeO	1.05
NiO	0.02
MnO	Trace
CaO	1.13
MgO	0.33
K_2O	4 46
Na_2O	4.21
P_2O_5	0.15
TiO_2	0.22
Total	99.81

Specimens taken from the summit of a high granite knob that occurs two miles northwest of the Silver mines, the top of which is capped by porphyry, yielding the following results to the chemist of the St. Louis Sampling and Testing Works :

	PER CENT.
SiO_2	74.12
Al_2O_3	13.82
CaO	1.41
K_2O	3.80
Na_2O	5.25

Mineralogical Constitution—What has already been said regarding the mineralogical composition of the granite applies also to the porphyry. The chief constituents are the feldspar and quartz, but the difference in structure of the rock gives them very different relationships. The accessories zircon, magnetite and apatite, are found scattered through the groundmass. The ferro-magnesian ingredients are not, as a usual thing, well developed. The feldspars are the same as those of the granites, and comprise the four varieties: orthoclase,

microcline, albite and oligoclase. They range from grains of microscopic dimensions in the groundmass to large phenocrysts, an inch or two in length. The porphyritic crystals of quartz are frequently rounded with the characteristic embayments, due to partial remelting before the original solidification of the mass.

Microscopical Structure.—The most striking differences between the granite and porphyry are shown when thin sections of the two rocks are examined under the microscope. The fine-grained matrix, in which are embedded the larger crystals, at once characterizes the latter. The groundmass varies considerably from the typical microgranitic structure to an almost glassy one which, however, is usually so thoroughly devitrified that its original character can hardly be recognized. The various phases which are especially noticeable, are the microgranitic, granophyric, micropegmatitic, felsophyric, vitrophyric and spherulitic. A particularly interesting facies is the trachytic, in which the minute crystals of lath-shaped feldspars

FIGURE 12. Magmatic corrosion of quartz.

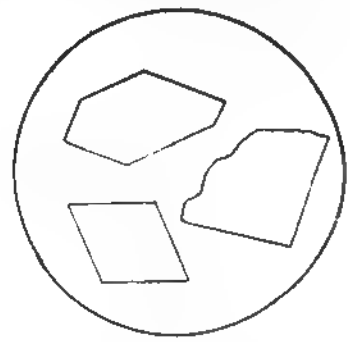


FIGURE 13. Quartz phenocrysts.

are arranged in the same way as in diabase. The phenocrysts are mainly quartz, though those of feldspar are not of infrequent occurrence. The appearance, under the microscope, of the porphyritic quartzes which have been rounded or given irregular outlines as the result of partial resorbtion, is represented above (figure 12). Some of the larger quartz crystals, however, preserve their crystallographic faces, and in thin sections give sharp, even outlines (figure 13).

Genetic Relations of the Acid Rocks—The fact that no sharp line of separation exists between the porphyry and granite, and that everywhere the two kinds of rock merge gradually into each other, the transition zone in different places varying from a dozen to forty or a hundred yards in width or depth, appears to afford good evidence that the rock masses represent, not necessarily numberless different eruptions as was once believed, but comparatively few with special differentation in the different parts. Since the structural character of massive rocks is dependent largely upon the accidental physical conditions under which the molten magma cooled and solidified, it is of prime importance to take into account the fundamental principles involved when considering the relations of the two rocks. Under ordinary circumstances, the texture of an igneous mass is glassy, or very fine-grained at the surface. Its grain becomes coarser as the distance from the surface increases. Granite is commonly regarded as an abysmal rock, one which has cooled very slowly and under great pressure. Porphyry is formed when the pressure has not been so enormous, and the cooling has been retarded less. At the surface, where solidification has gone on very rapidly and the pressure has been virtually wanting, amorphous glass is the result. All these stages may exist in the same mass, but secondary changes usually have obscured or obliterated the original features.

In the Mine la Motte district the conditions just described appear to have prevailed. Within the granitic area, where high, steep sided hills exist, the coarse-grained granite graduates upward into fine-grained varieties and finally into typical, aphanitic porphyry, which serves as a protecting cap to the elevations. Similar graduations upward of the granite into the porphyry in the isolated mountains are clearly observable in a number of cases, and it seems probable that these facts would hold true in most instances, if proper means of observation were afforded.

Within the limits of the sheet the principal granite masses clearly appear to be areas in which the superior surface facies of the acid magma had been removed through erosion; and the

physiographic features of the region point to the same conclusion.

Distribution of the Porphyries—The genetic relations of the porphyry to the granite, combined with certain physiographic peculiarities which exist in the region, give the rocks under consideration a somewhat anomalous position in their geographical distribution. The porphyries occur usually in isolated patches, for the most part of rather limited extent. The rocks either form or cap the highest hills. Many are found scattered over the southwestern two-thirds of the sheet, usually associated with granite, but often protruding above the sedimentary beds. In the same portion of the district is the largest area. It forms a part of a much larger field which extends farther to the west and south, beyond the limits of the sheet.

The most interesting areas are the smaller, isolated ones, especially those which occur in the large central granite region. The most northerly mass is at Knob Lick. It forms the summit of the hill, but descending the elevation in all sides, the rock gradually assumes a coarser and coarser texture, and finally graduates into coarse-grained granite.

On the lowland plain to the south of Knob Lick hill, the surface rock for a distance of several miles is almost midway in texture between granite and porphyry. A few hundred yards south of the old Skrainka quarry, there is a small area of granite in the northwestern base of a porphyry hill. On the west side of the same elevation a granite area similar to the one just mentioned occurs (Tp. 33 N., R. VI E., Sec. 9, NE. qr.). In ascending the hill toward the east the texture becomes finer and the quartz grains assume characteristic outlines until the rock is changed completely into a quartz porphyry.

Three miles northeast of the place last mentioned and about the same distance northwest of Mine la Motte station is another low mound where the transition from the granite to the porphyry may be made out readily.

A couple of miles west of Fredericktown Buckner mountain is composed chiefly of porphyry with small outcrops of granite at the base.

On the west bank of the St. Francois, about two miles northwest of the Silver mines, a small porphyry mass caps one of the granite hills.

DIABASE

Occurrence—The basic intrusions usually occur in well-marked dikes which cut through the granite and porphyry, or as in a few instances, in bosses almost circular in outline. The dikes vary in width from less than an inch to more than 150 feet. No general direction can be given as to their courses; but so far as observation goes, they appear usually to trend northeast and southwest, though in some instances they vary widely from this. The walls are generally nearly vertical (figure 14).

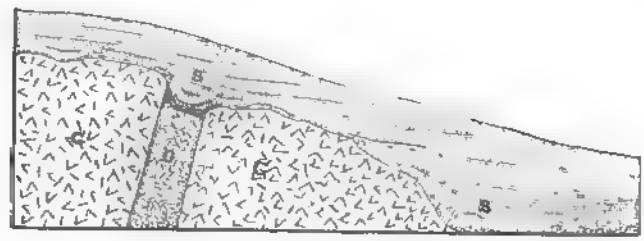


FIGURE 14. Dike in Granite at Silver Mines

The locations of the dike rocks are shown on the map. In many cases the limits of the dikes can not be defined on account of the heavy covering of soil and other residual products of decay. In many such cases, however, the location of a dike may be traced by the numerous bowlders of black trap-like rock lying on the surface.

Physical Characters—The basic rocks present a marked contrast to the granites through which they have been intruded. They are very dark in color, nearly black, very heavy, tough, and when struck with a hammer, gives forth the clear ringing sound of metal.

In texture the diabase rocks vary from perfectly holocrystalline to glassy. Where the conditions have been favorable for slow cooling, the rock is as coarse-grained as the granite, but at the sides of dikes where the molten material has come

into direct contact with the cold country rock, an amorphous glass has been formed.

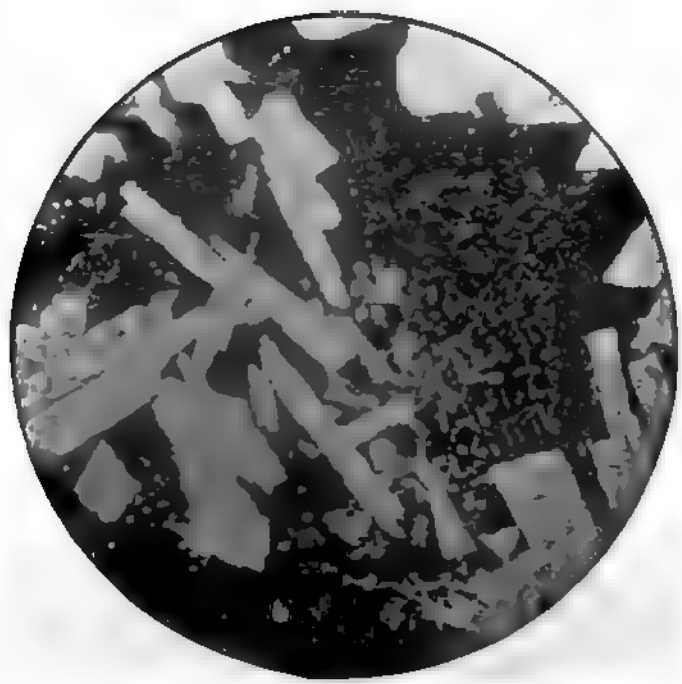
The porphyritic phase is not uncommon, and huge, white feldspar crystals buried in a dark groundmass form a striking combination. The phenocrysts usually have their crystallographic faces well developed.

Chemical Composition—The diabases have a comparatively low percentage of silica, about 50 per cent on the average. Free quartz is rarely present. The proportions of lime and soda indicate that the feldspathic components are labradorite and bytownite. An olivine-bearing diabase from Skrainka yielded the following results to the chemist of the St. Louis Testing and Sampling Works:

	PER CENT
Loss	0.26
SiO_2	46.94
Al_2O_3	16.91
Fe_2O_3	12.58
FeO	4.16
MgO	8.20
CaO	9.00
Na_2O	3.15
K_2O	0.54
P_2O_5	0.26
Total	100.74

Mineralogical Constitution—The basic dike-rocks are simple aggregates of plagioclase and augite, with olivine also in certain types, as essential minerals. The accessory components are magnetite, apatite and biotite. In the less perfectly crystallized dikes there is present much unindividualized material. As already stated, the feldspars are doubtless chiefly labradorite and bytownite.

Microscopical Structure—Great variety is presented in the minute structure. The holocrystalline rock, as shown in its typical development in thin sections under the microscope, is represented on the annexed plate vii, figure 1, while the variety contain much glass, and which may be called melaphyre, is represented on the same plate, figure 2; both are magnified 60 diameters. In the more glassy phases the augite crystals often



THIN SLICES OF BASIC ROCKS.

retain their crystallographic faces. The outlines of one is shown in the following cut (figure 15), in which also a glassy core is present in the crystal.

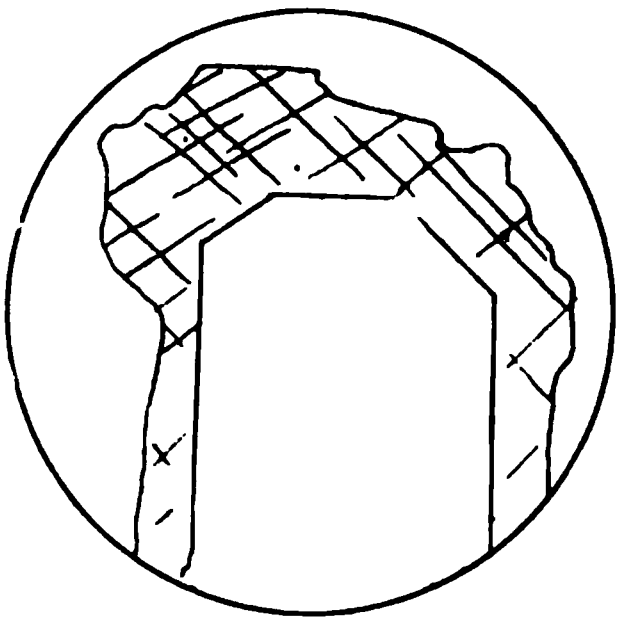


FIGURE 15. Augite Phenocryst, with glassy core

Location of principal dikes—The length and extent of the dikes are known in but few instances. Some of them which lie close together may, perhaps, belong to the same intrusive mass. The dikes are much more numerous in the southeastern part of the central granite area than elsewhere.

On Butler hill, west of Knob Lick (Tp. 34 N., R. VI E., Sec. 8, NW. qr.), occur numerous bowlders of dike rock. They trend northeast and southwest. Farther down the hillside to the northeast, a dike three feet wide, cuts through the granite. The two, doubtless, are parts of the same dike. To the northeast, a short distance, in a small quarry, a dike six inches wide is exposed in the granite.

Still farther to the east, bowlders of diabase appear at a number of places indicating the existence of dikes, but none are visible until a small quarry is reached on the northeast side of the mound, about one-half mile south of the Milne and Gordon quarry. Here is an excellent example of a small black dike cutting through red granite. Fragments composed in part of each of the two types may be obtained, the dike rock adhering to the granite with great tenacity. A fourth dike occurs in a quarry on the south hill face. The character of the rock is the same as the others in the area.

Two and one-half miles due south of Knob Lick station there a number of dikes whose locations are indicated by surface bowlders (Tp. 34 N., R. VI E., Sec. 21). They are found on the east side of the highway leading to Fredericktown. In three different places, each about 200 yards apart, the bowlders are found in great abundance. The south one seems to be the largest. The line of bowlders may be traced for some distance northeast from the road. As some of the bowlders are quite large, the dike is certainly three to four feet wide. The similarity of the rocks in the dikes indicates an intimate genetic relation. They are not very coarsely crystallized, and are composed of diabase-porphyrite.

At Rocky glen, on Rock creek, two miles north of the Mine la Motte dressing works, is an isolated dike. The stream passes between two sandstone hills. For a distance of 40 rods it has worn its channel through the sandstone to the crystallines. In a number of different places small dikes may be seen in the granite. At the point where the hills come closest together is a dike about forty inches wide which passes in under the sandstone. It is quite evident that the sandstone was formed long enough after the intrusion of the dike for the surface to be worn down to a level with the granite. In the bed of the creek, on the north side of a small granite mound east of the dressing works at Mine la Motte, a dike of diabase porphyrite is exposed. The surface covering entirely conceals it both to the north and south, so that it can be traced only a few feet. It is not over five or six feet wide, and it trends northeast and southwest.

Two miles west of Mine la Motte station (Tp. 34 N., R. VI E., Sec. 34), on the north side of a hill by the road is a small outcrop of dike rock, which is a good example of olivine diabase. The exposed area is small, and is occupied partly by bowlders, and partly by rocks rising three to four feet above the surface of the ground. These are portions of the dike which have resisted decay better than the adjoining country rock. The basic mass is very solid and compact, is coarsely

crystalline throughout, and is practically identical with the dike rock at Skrainka.

At Skrainka occurs a dike which is widely known on account of a paving block quarry which has been open in it. For years it has been worked for paving material which is sent into the market under the name of "blue granite." The quarry is located at the largest exposure of the dike. There are other outcrops near by which probably belong to the same intrusive mass. The rock is coarsely crystallized, of a bluish gray color, and is as typical an olivine diabase as there is in the region. The quarry is located on the southwest side of the hill, but the dike extends up a ravine to the east several hundred yards, and up a second small ravine to the northwest fully as far. The hill to the north is porphyry, which gradually changes into granite; that to the south and also the one to the west are of similar character. West of Skrainka less than a mile is another exposure of dike rock, which has been worked into paving blocks to a limited extent. Still further west is a second exposure of bowlders covering several acres of almost level ground. The dike itself is not visible. Across the ravine to the west, the presence of a third dike is shown by the occurence of numerous bowlders.

On the south slope of Skrainka hill, in a ravine running southwest, is a dike five feet wide, cutting porphyry. It trends north 30 degrees east, and has a number of small branches leading off from it nearly at right angles. It is very fine-grained, so much so that macroscopically it seems to be a perfectly homogeneous mass.

Along the Fredericktown and Ironton road, from three to five miles west of the former place, large masses of dike rock are exposed at numerous places. Some are badly decayed, while in the case of others there are large, fresh bowlders. A similar exposure also occurs a short distance south of the road near Frizzell branch. The character of these rock is the same as at Skrainka, so much so that specimens from the two places cannot be distinguished from each other.

On the north slope of Mount Devon, in the bed of a ravine opening into the Little St. Francois river, just above an old ford, is a dike seven feet in width. The characters of the rock are peculiar. About one foot of the mass on each side is the ordinary diabase, but the remaining portion is entirely different. Large crystals of a light pink feldspar are scattered through the rock, some of them being fully two inches in diameter.

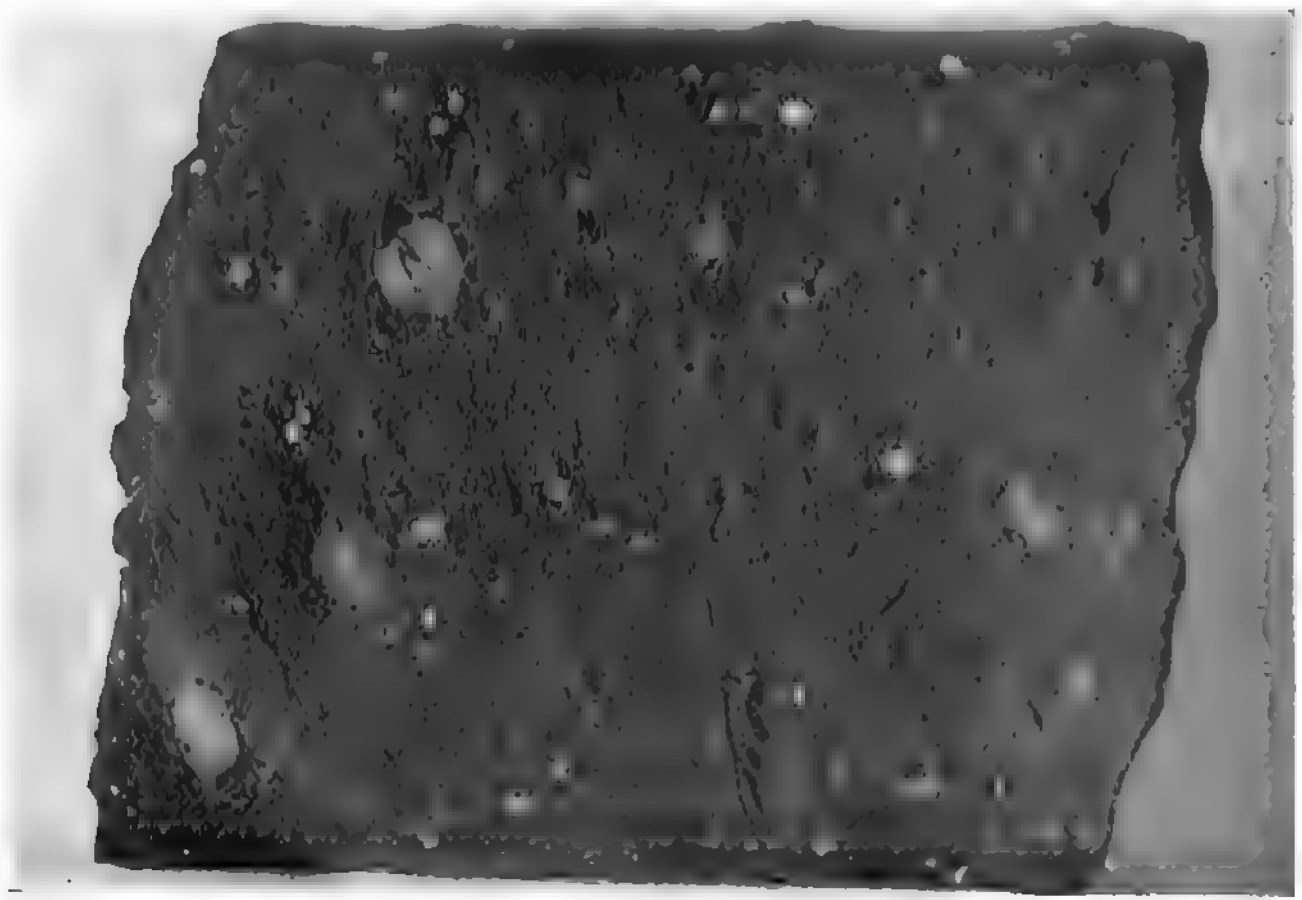
Another dike of coarsely crystallized diabase is located three miles to the southwest, in a branch of Matthew creek (Tp. 33 N., R. VI E., Sec. 28); and one also a little further to the southwest in section 31.

One of the largest diabase masses in the whole region is on the northwestern flank of Tin mountain (Tp. 33 N., R. VI E., Sec. 30). It is of particular interest on account of a great excitement which arose more than 20 years ago, concerning the supposed existence of tin ore. The dike is fully 50 yards wide at one place, and appears to cut into the northern side of the hill; but, as it cannot be found either to the north or south, it is probable that it is a boss, rather than a dike. The rock differs from that in and around Skrainka in being much less perfectly crystallized, and in having a darker color and a more waxy lustre. The microscope shows that fully one-fourth of the mass has never crystallized and, therefore, exists in the form of a glass.

East of Silver mines, on Pine creek, bowlders of diabase indicate the proximity of a dike several feet in width.

At and around the Silver mines are a number of dikes. On the left bank of the St. Francois river, just below the stone dam, a dike four feet wide cuts through the granite. It has yielded to decay rapidly so that it appears as a stair-case with granite walls. The rock is very fine-grained, dark-colored and contains much glassy matter. Across the stream another dike may be seen.

Back from the river on each side bowlders are quite common, although the dikes are not visible. At one place on the west side, about one hundred yards from the stone dam, bowlders



QUARTZ-DIABASE PORPHYRITE NORTHWEST OF SILVER MINES.

are found containing porphyrictic quartz crystals. The composition of the rock is about the same as the average small dike, excepting the presence of the free silica.

On the Dallas road leading west from the Silver mines, along the banks of a small branch, occur a great many bowlders of dike rock. About one mile to the northwest is a large area covered with diabase fragments, the arrangement of which indicates the existence of a basic boss, or large circular area, rather than a true dike. A little farther to the northwest is an unusually large number of bowlders, their position indicating a dike at least fifty yards wide. It is composed of a typical olivine diabase, and is very coarsely crystallized. Not far away is a very interesting dike which is about sixty inches wide. It trends northeast and southwest, and is in granite. The groundmass is fine-grained, and when examined macroscopically, seems to be a homogenous mass. It carries a large number of small porphyritic quartz crystals, with rounded and corroded surfaces, and also many pink feldspar crystals which are much larger, some measuring more than an inch in length. These crystals are principally orthoclase, although a few are of the more acid triclinic species. A silica determination of this rock gave 62.50 per cent. The appearance of the rock is well shown in plate viii.

On the southeast spur of Blue mountain (Tp. 33 N., R. V E., Sec. 22), are numerous bowlders. From their abundance at different points it is probable that more than one dike exists. This is the location of the so-called asbestos mine. Careful examination and considerable digging failed to find the mineral in place, though thin plates of it were found to occur in residual clays on the hillside.

Some of the smaller basic plates illustrate well the different phenomena accompanying dike formation. In one place noticed, fragments from the adjacent granite wall are broken off and included in the intrusive mass. Small tongues branch off at short intervals where there chanced to be branching fissures; and at one point the apophyces from the dike passed through other dike material, as is plainly shown by a marked difference

in color. It is not likely that this represents two distinct periods of eruption, but rather that the lava in the first narrow fissure cooled before the disturbance entirely ceased, and was afterward broken through by a new fissure which in turn was filled from below.

CAMBRIAN.

The stratified rocks of the Mine la Motte district comprise a succession of sandstones and magnesian limestones. They rest directly upon the massive crystallines. No strata younger than the Cambrian are believed to be represented. But few fossils have been found in the rocks of the area so that the faunal evidence as to geological age is somewhat meager.

Within the limits of the area three subdivisions of the Cambrian are easily made out. The members are sharply separated from one another by lithological characters, enabling them to be readily recognizable wherever exposed. The lowermost is the LaMotte sandstone; the median one, the Fredericktown limestone; and the uppermost, the LeSueur limestone.

LAMOTTE SANDSTONE

Mine la Motte sandstone is a name that has been applied to the arenaceous beds immediately overlying the Archæan rocks. It has never been properly defined as a geological term, though used specifically as a title to designate certain beds that are found in the vicinity of the Mine la Motte estate. Since the name was first used, the sandstone at the chief mine of the district has been traced for a considerable distance away, and the geographical extent accurately determined for the entire area occupied by the sheet. Arenaceous beds beyond the limits of the district have also been correlated with it. It appears desirable, therefore to retain the name La Motte for the sandstone in question, and at the same time to fix its application by a better definition of its essential features.

As shown in its typical development, the LaMotte sandstone is a rather soft, compact, medium-grained rock, composed

of clear quartzose grains, with more or less calcareous and magnesian material as the cement. In color it is brown, buff or white, but sometimes assumes dark brown, deep red or purple shades, especially in approaching the base where it rests on the old weather surface of the porphyry and granite. Usually the formation is homogeneous and massive or heavily bedded, though frequently thin limestone bands are intercalcated, and toward the crystalline hills, it has a tendency to become thinly bedded and shaly. Upward the sandstone often graduates into the limestone, the sand particles becoming less and less numerous and the calcareous matter more abundant until the change is complete. The thickness of the zone of transition from one to the other is sometimes not more than three or four feet. The passage from one lithologically distinct bed to another also takes place horizontally along the same stratigraphic planes.

At the bottom the arenaceous and argillaceous materials form the matrix for the conglomerate, made up of rounded, water-worn pebbles and bowlders composed of the underlying crystallines. The conglomerates are very changeable in lithological character and irregular in distribution. Moreover, they are not confined strictly to the base of the formation, but bowlder beds often occur some distance above the crystalline floor. At Doe Run, especially, are the granite pebbles thus disposed. In the mine at this point, rounded, granite masses of various sizes are encountered at the base of the limestone. One of the drill records (No. 4) of a hole put down southeast of shaft No. 2, gave the following succession:

VII. Section near Shaft No. 2, Doe Run.

		FEET.
12.	Clay, residuary, and soil	12
11.	Limestone, magnesian, white and yellow	29
10.	Limestone, gray	80
9.	Granite, bowlders	1
8.	Limestone, gray	8
7.	Granite, bowlders	1
6.	Limestone, gray	16
5.	Granite, bowlders	5
4.	Limestone, with small granite pebbles	6
3	Limestone, gray, with shale bands	5
2.	Shale, with granite bowlders	13
1.	Granite, solid (penetrated)	2

In geographical distribution the LaMotte sandstone presents some striking peculiarities. It occurs only in the Farmington lowland plain, of which it forms the median part, the granite on the west and the non-cherty magnesian limestones on the east constituting the other portions. Its principal development is around the borders of the large granite area, where it forms a sinuous belt from two to three miles in width. Its main body is thus semi-circular in outline. In the porphyry district, to the south, the sandstone area soon breaks up into small isolated patches, and its continuity cannot be traced. To the north in the vicinity of Doe Run it appears to thin out rapidly, and the limestone rests directly upon the crystallines, as is shown, not only by outcrops, but by diamond drill cores, which disclose the strata for depths of two to three hundred feet.

As a continuous formation, the sandstone at present is known to occur only within the boundaries of the sheet. Beds thought to be the same have been reported from neighboring districts, but as yet, there is no positive evidence of their exact continuity.

Although probably everywhere present just above the granite the bottom part of the formation, the conglomerate, is well displayed at comparatively few places. South of the Silver mines comglomeratic beds consisting of granite and porphyry pebbles and small bowlders are found interstratified with homogeneous sandstone layers. In the northwestern corner of Madison county, on Wachita creek, are also some good exposure of the conglomerates.

The geological position of the LaMotte sandstone within the area is manifestly at the base of the sedimentary rocks. Its upper limits is well defined by a heavy magnesian limestone of Cambrain age—the Fredericktown formation. There is usually little difficulty in making out its boundary above; but with the lower limit the case is different, though resting everywhere on the Archæan rocks. While the line of juncture with the underlying crystallines is even more pronounced than with the overlying limestones, the very uneven floor upon which the

sandstone rests makes the practical demonstration of the exact position of the line in any particular place one of considerable uncertainty. There are but few outcrops showing well the relations of the two formations. One of the best is on the Little St. Francois river, just below the railroad bridge, north of Fredericktown. (See figure 11.) The details have already been given in another place. The ancient granite knoll has been partially uncovered through very recent erosion. The old surface is quite steep, and upon it rests the sandstone which, however, is soon replaced by limestone. Farther downstream is a similar exposure on the opposite side of the knoll.

Near the mouth of Rock creek, north of the Mine la Motte estate, the line of juncture is shown in the bed of the stream. For some distance the sandstone is nearly white and rests at one point upon the summit of an old granite hill which has just begun to be unearthed. The base of the sandstone is somewhat coarser than it is above and contains a few small crystalline bowlders. There are also several other points in the vicinity of Mine la Motte which show practically the same phenomena. Other good outcrops exist south of Knob Lick.

The thickness of the sandstone varies greatly. Its present upper surface is about 900 feet above the sea level, and constitutes a part of the Farmington plain modified by recent erosion. The space occupied by it may be regarded as between this level and the uneven granite floor. It becomes attenuated over the old knolls, or thins out altogether against the larger Archæan hills; while in the ancient valleys it manifestly thickens very much. At Mine la Motte, a drill-hole (No. 211) put down at the western edge of Fredericktown limestone passed through 258 feet of this sand-

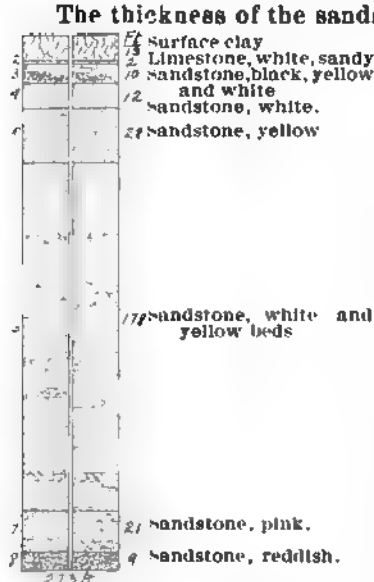


FIGURE 16. Thickness and Variability of LaMotte Sandstone.

stone. The dark red color of the rock at the bottom of the hole indicates that the drill had nearly reached the granite. The bed of limestone at the top, and the variability of the lithological characters of the sandstone are shown in the preceding cut (figure 16).

FREDERICKTOWN DOLOMITE.

The term Fredericktown is applied to the non cherty magnesian limestone, which forms a considerable portion of the surface of the Farmington lowland plain. It constitutes nearly all of the calcareous rock occurring within the area, and extends beyond the limits of the Mine la Motte sheet.

Two subdivisions rather distinctly marked are recognizable, the lower one being in the main an ordinary grayish limestone, with some sandy material and shaly layers, and occupying about one-third of the total thickness, or about 75 feet; and the upper one, a buff dolomite, tolerably free from silicious matter, and having a maximum thickness of over 200 feet.

The lower limestone is the chief ore-bearing rock, and is typically developed at the Mine la Motte, where it is well exposed on account of the extensive mining operations carried on in that vicinity. By the miners it is further separated into an inferior or "white rock," and a superior or "black rock," each portion containing a distinct ore bed.

The "white rock" is a light colored limestone, varying in places from white to gray or yellow, though some layers are often dark drab. It is more or less distinctly silicious, sometimes the silica being in a finely divided state and sometimes in the form of sandy material. The oolitic beds occur locally. At the mine the "white rock" has an average thickness of about 50 feet. In the middle is the lower ore horizon, called the "bluff" bed, from its principal development at the Bluff diggings. It varies from 5 to 10 feet in thickness, the average being about 7 feet.

The "black rock" is a dark colored often shaly limestone. It is drab or bluish below and becomes lighter colored above, and has a total thickness of about 20 feet. Numerous thin

beds of dark shale occur with some sandy layers. The shales contain myriads of little fossils—the *Lingulella lamborni* (Meek). The lower five or six feet make up the upper ore horizon, the "jack bed." It is distinguished from the lower ore stratum chiefly by the absence of silicious oolite and the presence of shale layers. The lithological details of the "black rock," as already given for the Rattlesnake diggings, section III, are as follows:

Details of Section at Rattlesnake Diggings.

		FEET.
16.	Limestone, thinly bedded, and drab shale	1.34
15.	Limestone, shaly	.52
14.	Shale, clayey	.25
13.	Limestone, shaly	.17
12.	Shale	.36
11.	Limestone	.35
10	Shale	.13
9.	Limestone	.81
8.	Shale	.56
7.	Limestone	1.31
6.	Shale	.20
5.	Limestone, light drab, with reddish drab blotches	1.42
4.	Shale	.40
3.	Limestone, thinly bedded, with clay partings, lighter colored than below	.54
2.	Limestone, heavily bedded, blue and gray, with tendency to slaty structure	3 00
1.	Limestone, same as No. 2, with galena (jack bed)	7.00

The location being near an old granite hill the characters as here exhibited probably do not extend very far, though they are similar at the Jack diggings on the opposite side of the crystalline mass.

Above the section at the Rattlesnake diggings the massive magnesian beds set in. These form the principal portion of the Fredericktown beds. As typically developed on the Little St. Francois river north of Fredericktown (figure 11), it is a buff to brown, compact, heavily bedded dolomite. Sometimes sandy beds are intercalated, but usually only when the calcareous strata approach the crystallines. As a rule, there is not much silicious matter. A chemical analysis of beds exposed on Rock creek north of Mine la Motte gave:

	PER CENT
$CaCO_3$	52.10
$MgCO_3$	43.92
Al_2O_3	1.85
FeO	0.94
Undetermined	1.19
Total	100.00

The proportion of lime and magnesia is very close to the theoretical amount for true dolomite.

As a part of the Fredericktown formation there occurs in the southwestern part of the sheet a few small areas of what are known as the marble beds. These are hard, compact, fine-grained rocks, which are susceptible of taking a high polish. They occur in massive layers and may be taken out in large blocks. There is a wide range of colors displayed, from pure white, gray, yellowish, pink, reddish to dark red or brown. Often the various colors are blended, giving a mottled appearance to the rock. In the large area at the mouth of Cedar creek some rather unique phases are presented. These are best shown at the Allen and Smith quarry (figure 17.).

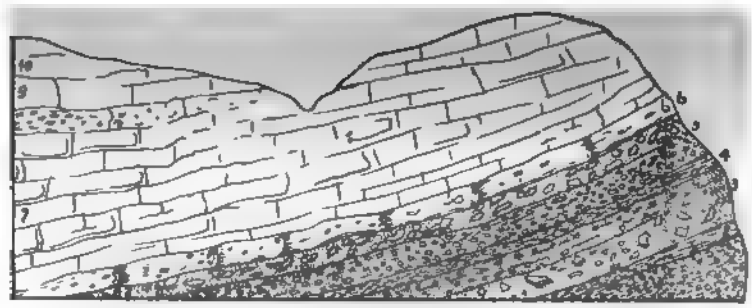


FIGURE 17 Marble beds with intercalated porphyry fragments.

VIII. Section at Allen and Smith Marble Quarry.

		FEET
10	Residuary deposits	4
9.	Marble, compact, red	8
8.	Marble, with fragments of crystallines	5
7.	Marble, grading laterally into conglomerate	8
6	Marble, with large porphyry fragments	1½
5	Conglomerate, coarse	4
4.	Shale, red, in part pebbly	2½
3	Conglomerate, coarse	8
2	Shale, red, with small bowlders	3½
1.	Shale, red, in part containing crystalline pebbles (exposed)	10

The marbles appear to be locally altered limestones or dolomites. A complete change from one to the other often takes place in the same stratum within a distance of a few hundred feet. This transition is well exhibited just outside of the area at the Heberner quarry, on Marble creek (Tp. 32 N., R. V E., Sec. 17). The marble beds are continuous for a distance of perhaps 100 yards, but on each side of the quarry merge into ordinary limestones.

The geographical distribution of the Fredericktown limestone presents some noteworthy features. Within the limits of the sheet the formation occupies a broad curved belt, extending from the northwest corner eastwardly and southeastwardly to the eastern margin of the district and thence southwardly and southwestwardly. North of the sheet it is recognizable for a considerable distance, and southward, at least across Madison county. Farther than this its limits have not been traced with precision. It forms the eastern third of the Farmington lowland plain and is bordered on the east by the more or less pronounced escarpment formed by the higher cherty limestone of the LeSueur formation.

In the west the underlying LaMotte sandstone is the surface rock and cuts off the limestone in this direction. In a few places the crystallines form a portion of the boundary. At a number of points the ancient Archæan hills protrude above the limestone surface.

The geological position of the Fredericktown limestone is near the base of the Cambrian as represented in southeast Missouri, above the LaMotte sandstone, but below the LeSueur formation. However, in the area occupied by the Mine la Motte sheet there are often certain peculiarites in the distribution that prevents this stratigraphic sequence from being always made out clearly. The cherty limestone only overlies the non-cherty rock in the extreme northeastern corner of the sheet. In some places, as in the vicinity of Doe Run, a similar somewhat cherty limestone rests directly upon the crystallines. Near Fredericktown only a few feet of sandstone intervenes between the limestone and the granites.

The faunal features of the limestones are not conspicuous. With the exception of one or two places, fossil remains are very meager. The Linguella beds, best exposed at the Jack diggings on the Mine la Motte estate, lie about a dozen feet below the principal dolomitic number, and just above the upper ore horizon. In the thin blue shales the layers are often crowded with shells. Only a single species, *Linguella lamborni* (Meek), has been found. In the gray limestone at the Doe Run mines a similar but smaller form of Linguella has been obtained in the cores of the diamond drill, at a depth of over one hundred feet. Near Fredericktown fragments of fossils have also been obtained. The peculiarities of the Linguella shells has assigned the beds containing them to the Upper Cambrian.

LESUEUR DOLOMITE

Above the magnesian beds of the Fredericktown formation there is a very cherty dolomite which, within the district, attains a thickness of fully 250 feet. The name is derived from a conspicuous hill made up almost entirely of the formation, and lying on the headwaters of Rock creek. It is called after the discoverer of lead in Missouri. The chert occurs in nodules and nodular layers and in places makes up over one-half of the bulk of the formation. In breaking down under the action of atmospheric agencies the chert-bearing beds resist weathering influences much longer than the non-silicious underlying limestone. As a result the high grounds which are composed of the beds of this formation are deeply covered by chert, so that the local appellation of "flint-hills" is a very appropriate term. The underlying members the non-cherty Fredericktown limestone wears away much faster than the LeSueur beds, and as a consequence wherever the former beds are overlain by the latter, a more or less abrupt escarpment is found which constitutes one of the most marked physiographic features of the region. In many places over the area occupied by the Fredericktown limestone and from which the LeSueur formation has been removed through erosion there are often thick deposits of

residuary chert. It doubtless represents all that remains of the beds belonging to the higher horizon.

In lithological character the LeSueur beds are sharply contrasted with the underlying strata. The layers are not so thick, the presence of large quantities of chert giving the beds quite a thin-bedded aspect.

Within the limits of the Mine la Motte sheet the LeSueur limestone is not a very important formation but elsewhere its geographic distribution is quite extensive. Only a few of the rugged chert-covered hills in the northern portion of the area are composed in part of it. In the eastern part of the Mine la Motte estate the steep-sided elevations made up almost entirely of this formation rise from the channel of Rock creek. From this point nearly to the northern border of the sheet it forms an irregular belt, from one to three miles wide, within the district, but extends much farther to the east. In the northeast corner of the area there is another small development.

GEOLOGICAL STRUCTURE.

GENERAL RELATIONS OF THE FORMATIONS.

In its main features the geological structure of the region covered by the Mine la Motte sheet is simple. But while there is relatively great simplicity as regards deformation there are more or less complicated characters which are the result of discordant sedimentation. Between the two principal formations, the massive crystallines and the bedded rocks, there is a remarkable and profound unconformity which gives rise to great intricacy in the stratigraphy of the region. The stratified rocks, however, form a regular conformable sequence from bottom to top, and although the lithological characters change rapidly from place to place and from one level to another, little difficulty is encountered in making out the stratigraphical details.

For the most part the inclination of the strata is slight, usually hardly perceptible. In the vicinity of the old granite and porphyry elevations with their steep sides the slant of the

principal planes of stratification corresponds to the slope of the old buried hills, but a short distance away the beds become practically horizontal. This declination around the porphyry prominences is often as much as 20 to 25 degrees.

Notwithstanding the fact that the strata have not undergone marked folding or other profound deformation, there are considerations to be emphasized, which are of the greatest importance from an economic standpoint and at the same time of much interest scientifically.

With considerable detail there has been already given a description of the local and general lithological characters of the various rock masses. In a broad way all of these diverse masses may be brought together so as to form a few distinct groups or geological formations. Their number and general relations may be inferred from the table of formations and the general vertical sections. But the exact relations which the formations bear to one another over wide areas is displayed best by geological cross-sections along critical lines or those lines which are best calculated to disclose the many different features of both original and acquired structure.

GEOLOGICAL CROSS-SECTIONS.

Smith—LeSueur Mountain Section.—Smith mountain is in the southwest corner of the district. Mount LeSueur is near the central point of the east boundary of the area. The section connecting the two elevations is about eighteen miles in length. It traverses the three physiographic belts and crosses the median one, the Farmington lowland plain, nearly at right angles to its main trend. The line of the section passes over every geological formation represented within the limits of the sheet. (See plate iii, figure N-O-P.)

The foundation of all is manifestly the coarse-grained red granite. Upon its upper uneven surface the sediments rest, most of the deposits occupying valleys or basin-like depressions. The stratified rocks are everywhere nearly horizontal except in the immediate neighborhood of the old crystalline elevations, where the strata rise more or less abruptly, and the

dips are often quite marked. Around the old elevations the strata slant away in all directions. The most instructive part of the section is the northern half, the portion in which the sedimentary strata are the surface rocks. The LaMotte sandstone covers a considerable part of the distance between the granite area and the extremity of the section. At the point where the Fredericktown limestone begins to appear, drill records show that the sandrock attains a thickness of over 250 feet. Near Rock creek the change from sandstone is very abrupt and on the same level. Diamond drill-holes and the section along the stream at this place indicate clearly that a fault of not less than 300 feet exists, bringing the base of the cherty limestones nearly down to the level of the top of the sandstone, and almost hiding from view the Fredericktown dolomite. The details of the fault are shown in another place (figure 25).

Wachita Mountain—Big Hill Section—The course of the section is across the sheet in an east to west direction. The location is near the southern boundary line of St. Francois county. It is a section across the lowland plain and meets the Smith mountain and LeSueur section at the eastern margin of the sheet, on the flank of the escarpment of the upland plain. The details in the eastern part are essentially the same as in the section just mentioned. In the western half the granite field is crossed. At Knob Lick hill the porphyry forms the upper part, and the granite the lower.

Mine la Motte Section—The line of this section runs nearly east and west through the central part of Mine la Motte estate. The most of the sub-structure is coarse-grained granite, though Bald mountain is composed of porphyry. The basal sandstone appears in a small, basin-like depressions in the granite field. The porphyry mountain just alluded to protrudes above the sandstone, which is the typical LaMotte formation. At the edge of the limestone the basal sandstone is, as already stated and as shown by diamond drill holes, over 250 feet in thickness. The overlying limestone, Fredericktown formation, rests directly upon granite, in a knoll which is exposed at the surface

a short distance east of the main mines. The sandstone doubtless surrounds the old hill, but its summit is higher than the top of the sandstone, thus bringing the limestones down to the crystallines. A fault of considerable throw occurs just beyond the east end of the section. The relations are shown in a similar way in the annexed cut (figure 18).

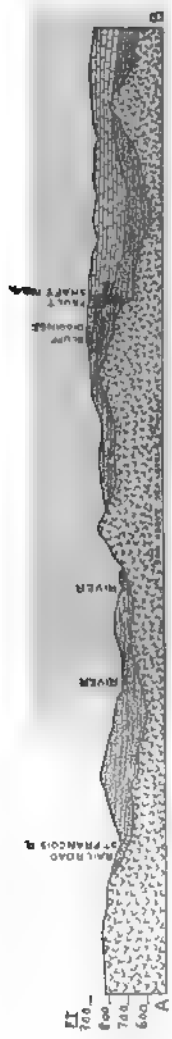


FIGURE 18. Cross-section through the Mine la Motte Estate.

Knob Lick Section — The cross-section which embraces Knob Lick hill, the center of numerous quarries, is instructive on account of being in the midst of the great granite field. The elevation is capped by a considerable thickness of porphyry which graduates downward into the coarse-grained granite. This is a type of a number of hills which exist in the central granite field.

Fredericktown Section—Although the extremities are four miles apart, the section under consideration is essentially a continuation of that of Knob Lick. It passes directly through the typical location of the Fredericktown limestone. It reaches from the outliers of the central granite field southeasterly to several isolated porphyry hills. At the bottom of the limestone, where this approaches the crystalline elevations, the basal sandstone and its associated conglomerate bed are very thin, bringing the calcareous member within a few feet of the massive rocks. The details of the succession and the arrangement of the several beds are especially well shown one mile north of the Little St. Francois river (figure 11 and also plate vi).

Devon Mountain Section—In direction the section is north and south. It passes through the limestone belt in an area where the crystallines protrude in numerous places. Devon and Buckner mountains are steep porphyry hills, with the Little

St. Francois river flowing between in a narrow gorge, known as the shut-in. They rise out of the limestones plain and have little or no sandy material on their slopes. The northern end of the section touches the central granite field.

Tin Mountain Section—This section extends in and east and west direction from Matthews creek to Smith mountain, connecting at the latter point with the section running to mount LeSueur. The most extensive marble beds within the area of the sheet are immediately west of Tin mountain, and the relations with basal sandstone are well shown. A large basic dike or boss occurs near the base of the mountain on the south bank of the Little St. Francois river. A similar dike also exists a couple of miles to the eastward.

Doe Run Section—The mines of this district are in the extreme northwestern corner of the sheet. The cross-section extends north and south near the western boundary of the sheet, from Doe Run to the Wachita and Big Hill section. It crosses an area in which the limestones rest directly upon the granite. Considerable sandy material together with crystalline bowlders occupy the depressions in the granite, and this is also the ore horizon. Further details are shown in a section taken in a little different direction (figure 19) and also a smaller cut representing the formations existing at the shaft (figure 20).

DEFORMATION.

Although the area forms a part of the Ozark uplift, where dynamic forces have operated on a large scale, the bowing of the strata has been regional in character and the local effects have not been marked. Of folding there has been practically none that is perceptible within the district. Only unimportant undulations have been observed. As a rule, they are so slight that they cannot be detected without careful measurements being made. The marked inclination of strata which has often been ascribed to low folds, is the result of peculiarities in the original deposition of the beds, and not of deformation after sedimentation had ceased. Very noticeable dips are apparent where the stratified rocks rest upon the ancient crystalline hills.

UNCONFORMITIES.

In no part of the state is discordance between formations more marked than in the Mine la Motte sheet. The most marked irregularity in the even succession of the rocks is between the crystallines and the sedimentaries. It is clearly shown in all the cross-sections and in numerous other sections of which mention has been made of only a few.

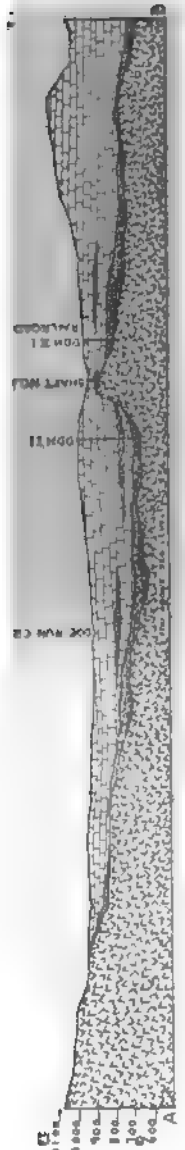


FIGURE 19 Cross-section through Doe Run Mines.

The physical break between the formations of the two classes of rocks is very much more than an ordinary unconformity in which, owing to a warping of the earth's crust, the parallelism between two formations is not preserved. The surface upon which the sediments were laid down was very uneven. (See plate vi and also plate ix.) It was manifestly an old land surface deeply cut into valleys and ridges, presenting even greater contrasts of relief than is indicated in the present topography. The juncture of the sedimentary formations and the crystallines is nearly everywhere marked by a bowlder bed, or conglomerate, of greater or less thickness. Usually there are only a few feet of conglomerate, though bowlders are often found as much as 50 or 60 feet from the base. The strata resting on the conglomerate may be sandstone or limestone—usually the former. The characteristic arrangement is shown at the Doe Run mines (figure 19). At the shaft which was sunk on top of a steep granite knoll, as shown by drill-holes, the limestone rests directly upon the crystallines. The details are shown in the accompanying cut (figure 20).

CAMBRIAN SANDSTONE RESTING ON GRANITE.

PORPHYRY BLUFF SHOWING JOINTING PLANES MOUTH OF LITTLE ST FRANCOIS RIVER.

PORPHYRY NEEDLES ON BLUFF OF LITTLE ST FRANCOIS RIVER.

PORPHYRY NEEDLES ON BLUFF OF LITTLE ST FRANCOIS RIVER.

JOINTING.

The phenomenon of jointing is well developed in many parts of the district, especially in the crystalline rocks. In the region under consideration, jointing appears to be due to several different causes. In part it is evidently the result of contraction of the rock masses. There is no doubt, however, that not the least important factor in the production of jointing has been torsion arising from orogenic strains.

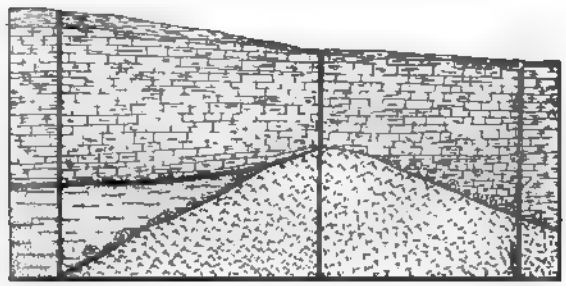


FIGURE 20. Stratigraphical Details of the Doe Run Shaft.

In the crystalline rocks where jointing is well displayed several distinct sets of fracture planes have been made out. The leading or master plane has a general direction of north 60 degrees east. The principal secondary joints intersect the first at angles of 80 and 100 degrees. The natural cleavage planes pass from one lithologically distinct rock to another without change of course. In the hard brittle porphyry the fracture planes are much more numerous than in any other variety of rock and extend to great depths. Those which occur near the mouth of the Little St. Francois river (plate x.) are so close together as to give an appearance similar to that observed in the case of basaltic columns, though the regularity is not so pronounced. Single needles are shown in plate xi. In the granites the joint planes are usually much farther apart than in the porphyry, and advantage is taken of the fractures in quarrying.

The trend of the master joints coincides approximately with that of the dikes so that the latter may be regarded as filling the fissures formed by the forcing apart of joint walls.

DISLOCATION.

While there are evidences of an extensive system of profound jointing there are rarely indications of marked displace-

ment between the parts adjacent to the fracture lines. The faults observed are usually of small throw, and where most carefully investigated in the mines, appear to partake of the character of step faults, altogether frequently forming displacements of considerable extent.

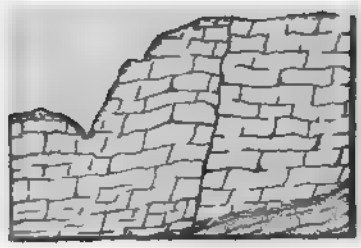


FIGURE 21. Small Fault north of Fredericktown.

Small faults occur at many points throughout the area. On the Little St. Francois river, one mile north of Fredericktown, is one of less than one foot throw (figure 21). It is in the Fredericktown dolomite. This may be regarded as typical of a large number.

At the Doe Run mines displacements of only a few inches are well displayed in connection with the ore beds, one of which is represented in figure 22. A noteworthy feature of the faults here is that the trend is about the same as the secondary series of principal joint planes, which traverse the regions north 50 degrees west.

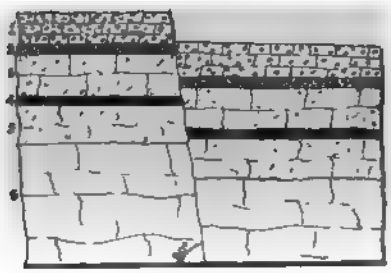


FIGURE 22. Fault at Doe Run Mine.

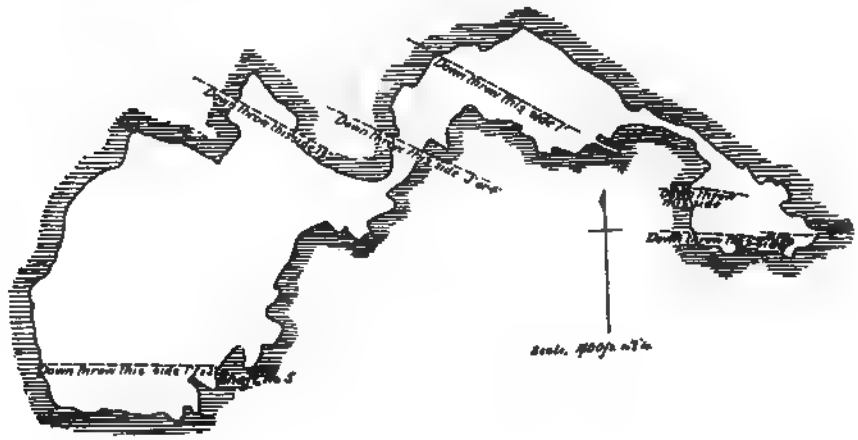


FIGURE 23. Faults in Mine la Motte Shaft No 5

In the various mines on the Mine la Motte estate many faults have been encountered. In shaft No. 5 occurs a series of parallel dislocations (figure 23), none of which have a displacement of more than five or six feet. The four other shafts also have similar faults of small throw running through them, some of which attain a fall of ten or a dozen feet. They are found well displayed on both levels of the mines.

There are, however, some faults of greater magnitude than

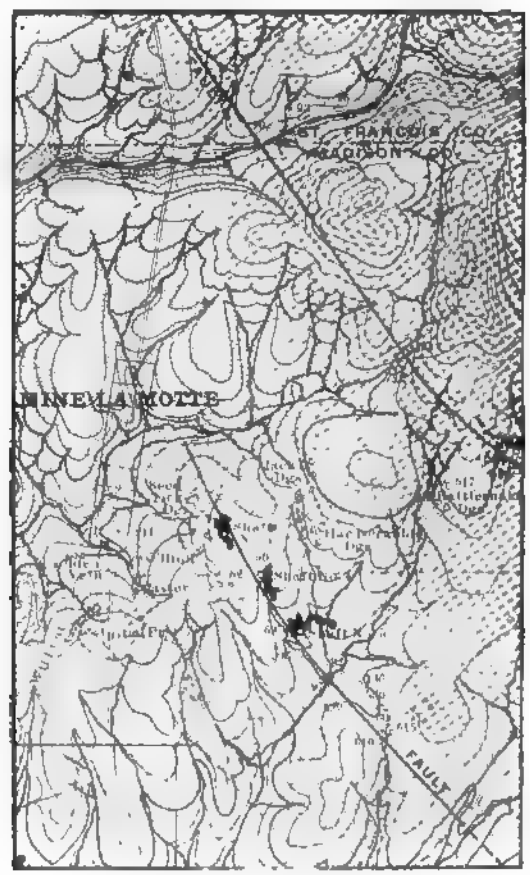


FIGURE 23 Principal Faults at Mine la Motte.

any of those mentioned. On one of them the principal shafts are located. It has the same general trend as the smaller ones.

Drill-holes indicate that the beds on one side have dropped at least 170 feet. Finally towards the southeast the throw appears to grow rapidly smaller. The relative locations of the shafts, faults and drill-holes are represented on the accompanying sketch (figure 24).

The drill-holes were started on ground which was very uneven. In order that the real relations of the records may be seen clearly and the proper interpretation placed upon them, the starting points have all been reduced to a level of 850 feet above tide. There is a close agreement on the one hand of those borings put down on the southwest side, and on the other hand of all those sunk on the northeast side; while there is a marked desparity between the two sets. The comparison is indicated in the table below:

Southwest of Fault			*Northeast of Fault.*		
Drill hole No	Surface Alt	Depth to SS.	Depth to SS.	Surface Alt	Drill hole No.
	Feet A. T.	*Feet.*	*Feet*	*Feet A. T.*	
92	950	87	70	900	80
60	960	81			
97	950	42			
			126	850	92
97	810	14	171	920	136
532	830	18	161	920	530
			148	880	542
			136	835	606
610	840	71	185	840	615

About a mile to the east, a fault of even greater throw occurs. It is well shown north of the mines on Rock creek, just above the crossing of the Libertyville road. Borings have been made in this vicinity, which, taken together with the evidence displayed along the streams, indicates that a drop not less than 210 feet exists. The details, as depicted by Winslow, are represented in the accompanying cut (figure 25). For some distance above the crossing of the wagon road, the bluffs are quite prominent along the stream. At one point the

limestones are abruptly replaced on the west by sandstones of the same level, suggesting that some dislocation has taken place.

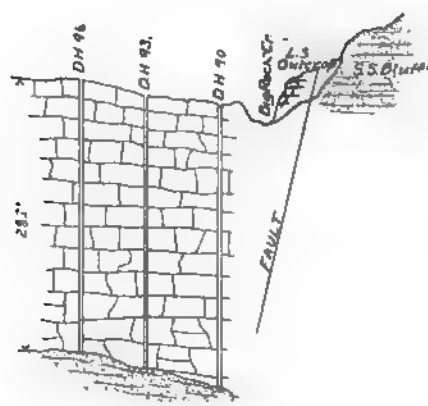


FIGURE 25 Details of fault on Rock creek.

A number of diamond drill-holes have been put down at short intervals along the creek east of the point where the sandstone bluffs are replaced by limestone. One of them (No. 93), passed through 285 feet of limestone (Fredericktown formation) before entering the sandstone (LaMotte). Two other holes near by give similar results.

Southeast of the place, on Rock creek, where the evidence of a dislocation appears, additional drilling has been done with a view to locating the fault. Two borings were begun at nearly the same level, and about 50 feet higher than those further north. One (No. 732) reached the sandstone at a depth of 108 feet. Another (No. 739) located about 200 yards to the northeast, passed through 564 feet of limestone before reaching the sandstone. Still further to the southeast, perhaps three-quarters of a mile, other borings were made. Similar conditions were revealed. One of the northernmost holes (No. 694) penetrated the limestone 479 feet, entering calcareous layers containing feldspathic material, which were evidently not far from the crystallines. About 300 feet to the southward a second drill-hole (No. 796) reached the red porphyry at a distance of only 76 feet from the surface. The surface upon which the borings were started are practically on the same level.

Connecting the several points, the line of the fault coincides closely in the direction with those of the smaller slips observed in the mines, or north 50 degrees west. While the fault has not been traced northward very much farther than Rock creek, the physiographic peculiarities on the Little St.

Francois river several miles beyond, would indicate that the dislocation reaches at least that far.

The hade of the faults is toward the northeast, usually from 10 to 15 degrees.

MINERAL VEINS.

In the present connection reference is made only to the mineral veins, the material of which has come up from beneath through fissures. They thus differ very much from the common vertical crevices, the vein stuff of which has been precipitated without having been in a heated state. The principal occurrences of this kind in Missouri are in the area covered by the Mine la Motte sheet, and chiefly at the Silver mines in the west-central part of the district. The characters at this point are fully described in another place in connection with the account of the mine.

Similar quartz veins also occur in Madison county just beyond the southern boundary of the sheet.

LEAD.

In the Mine la Motte district the occurrence of lead deposits has been known since the early part of the eighteenth century. The first mining was begun about the year 1720. Since that time the ore has been taken out with little interruption to the present day.

ORE DEPOSITS.

With one or two exceptions the depositions of lead ore have been by metasomatic replacement. Only at the Silver mines and at a few other points are there evidences of the metal having come up from below through fissures. At all of the principal localities where the ore has been developed the genesis and arrangement of the deposits is practically the same.

At the Mine la Motte, the engineer in charge, J. E. Mills, was the first to give a detailed statement of the ore and its occurrence. The following account concerning the lead deposits and mines of the district covered by the sheet are abstracted

chiefly from the recently issued report of the Missouri Geological Survey on the lead and zinc deposits of the state.

There are three principal modes of occurrence: (1) The most common is the disseminated ore, in which fine particles and irregular masses, as well as crystals, mostly imperfect, are arranged very irregularly in discontinuous layers. They may be sparingly scattered or they may form almost the entire stratum. In the more common occurrences the masses are from one-eighth to one-half of an inch in size and freely distributed. (2) The next variety has the clean mineral deposited in horizontal and vertical sheets of varying thickness, from a fraction of an inch to several inches, but usually measuring about three-eights of an inch through. These sheets are formed along joint planes where the two parts of the original rock has been separated slightly, or the crack has widened through solution. (3) The third mode is the pocket deposit. The calcareous rock has been dissolved and cavities have been formed. Afterward they have become partly or completely filled with crystallized galena. Instead of being made up of perfect crystals, as would be expected, there is here and there a brilliant cube, perhaps nearly perfect. Around it and making up the greater portion of the galena in the pocket are imperfect crystals with a soft, earthy coating.

By far the great mass of ore mined consists of the disseminated galena, and this has long been the chief source of supply. "Featherstonhaugh describes it as being quarried in 1836. Galena is also disseminated through sandstone in places, into which the limestone frequently grades, though it is less abundant in the sandy portions. During the earlier surface work, a good deal of cerussite was obtained. The disseminated ore is recognized as occurring principally at two horizons, but in these the ore varies in quantity, being most abundant in rocks of open, porous texture, and also in portions that are traversed by faults and crevices. The limestone of the upper horizon is known as the 'black rock,' of the lower as the 'white rock;' the ore is more persistent in the white rock, and toward the east

the black rock becomes gray. These rocks differ merely in color, from contained iron or other impurities, and are, hence, not always separable. As developed by recent drill-holes they are found to have an aggregate thickness of from 70 to 144 feet, sometimes separated by about six feet of gray limestone. They correspond to Mills' upper and lower sub-groups. They dip slightly to the east, away from the Archæan area, cropping out near the western limits of the limestone as shown on the map. Along these outcrops the early shallow diggings were distributed. In the 'black rock,' near its base, is the upper ore bed, which Mills termed the 'Jack' bed. The thickness he found to be normally seven feet, but sometimes as much as 11 feet; and above this for six or seven feet, more galena was found in films along joint planes and crevices, and also in bunches. The available galena from the bed, as developed up to 1877, was equivalent to a solid layer, averaging 2.55 inches in thickness. Associated with this bed, most of the copper and iron pyrites carrying nickel and cobalt were found which, intermixed with the galena, occupied large, flat, lens-shaped portions of the ore body. The 'white rock' carried what Mills terms the 'Bluff' ore bed. It is defined as occupying a position 15 to 30 feet above the base, but later developments show it often near the top of the 'white rock,' so that the two ore beds are sometimes in contact. The thickness is generally about seven feet, but ranges from five to eleven feet. About 40 per cent of the entire area of the bed had been profitably worked up to the time of Mills' report, and the average thickness of the workable portions were estimated to be 1.4 inches. "The principal mineral associates are calcite, iron pyrites and the rare cobalt-nickel sulphides; galena, calcite, dolomite and pyrite crystals are found lining small cavities, and also along crevices; calcite is also found in large crystalline masses embedded in the limestone."

At the Doe Run mines, in the extreme northwestern corner of the sheet, the ore is similarly disposed. Galena is the chief ore, and occurs normally disseminated through the limestone in crystalline grains or small masses, "principally between

depths of 50 and 90 feet. It is generally in layers parallel to the stratification, but is also along vertical and inclined seams, or is uniformly disseminated throughout the rock." The ore lies principally in the dark grayish limestone which is irregularly banded and dotted with lighter colored calcareous rock. It is quite hard and usually compact. At a number of places in the workings the granite floor has been foliowed. In such cases the ore has been found to extend all of the way down to the solid crystalline rock and in the lower few feet of limestone. Numerous bowlders and pebbles of red granite, such as make up the bed rock, also occur in the limestone just above the solid granite, and frequently the galena is disseminated in the matrix enclosing the bowlders. Sometimes these rounded masses are a foot or two in diameter and have lead ore spread over the surface. In the common occurrence, in which the lead ore is in disseminated grains or particles more or less finely crystallized in light gray to buff limestone, some of the strata are made up to a large extent of the ore alone. Streaks and crevices of the mineral are quite common in certain layers. Shale is sometimes encountered. It varies in thickness and is of a dark grayish green color, banded with lighter streaks; it contains numerous galena crystals, usually about one-eighth of an inch across.

Cavities lined with galena crystals are much less common than at other points in southeastern Missouri and there is also fewer minerals associated with the ore. Calcite is rarely shown. Pyrite is more often present, and with it is a percentage of nickel.

Galena also occurs in another way, in fissure veins. On the St. Francois river, at a point known as the Silver mines, a vein six feet wide cuts the red granite in a direction south of west. The gangue is chiefly quartz with silver-bearing galena, iron and copper pyrites.

LEAD INDUSTRY.

MINE LA MOTTE.

The history of the mining operations which have taken place since the first opening has been so recently given fully

in other reports of the Missouri Geological Survey that it is unnecessary to repeat it. On the LaMotte tract there have been a number of shafts put down and many diggings opened up. The former have been sunk chiefly along the line of one of the principal faults; while the latter have been operated east of the village around the margin of a granite knoll, which protrudes above the limestone.

There are now three openings in active operation. Shafts No. 1 and No. 2 are about 100 feet apart, and the workings are considered as one. Only from the latter is ore taken out. Shaft No. 4 is a short distance to the southeast, and No. 6 to the northeast. Shafts Nos. 3 and 5 were opened up, but have not been operated much. Some work is also going on in the surface diggings southeast of the dressing works and near shaft No. 4.

Shaft No. 2.—Since mines Nos. 1 and 2 have been connected underground only the second is used for ore raising, the first serving as an air-shaft. From the first opening the workings have been extended 400 feet in one direction and 600 feet in another. The record of drill-hole No. 31, which corresponds to shaft No. 1 is as follows, numbers 11 and 12 constituting the "black" rock and numbers 2 to 10 the "white" rock:

Section at Shaft No. 1.

		Feet.
17.	Clay, residuary	12
16.	Limestone, "caprock"	3
15.	Limestone, blue	16½
14	Shale	1-6
13	Limestone, blue, slaty seams	22½
12.	Galena, nearly pure	½
11	Limestone, blue, with galena and pyrites	7
10.	Limestone, white, with traces of galena	2½
9.	Limestone, white, with traces of pyrites	16½
8	Galena, nearly pure	½
7.	Limestone, white, with disseminated galena	3
6.	Galena, nearly pure	½
5.	Limestone, with disseminated galena	4 1-6
4	Limestone, white	3¾
3.	Limestone, white, with traces of galena	12½
2	Limestone, white, very rich in galena, also bears much pyrites	6
1.	Sandstone, white	½

Galena is first found at a depth of 53 feet. From this horizon it occurs either in nearly pure layers or well disseminated in the limestone to a depth of 116 feet. Only about

one-third of the interval between the two extremes is entirely barren rock. The work has progressed mainly to the north of the shafts in both the "black" and the "white" rocks.

At a number of points faults of small throw occur. In the greatest, called the "main" fault, there is a drop of 10 feet. The strike is north 62 degrees west; the hade 10 degrees to the northeast. "Adjacent to this fault, the rock was rich in galena on the south side; it was here of open texture, containing small cavities lined with calcite and galena crystals, and these were also found along narrow crevices which traverse the rock. Crushed fragments of rock, with rounded and smooth surfaces, were visible along the fault planes. This fault can be traced for a distance of about 300 feet. Proceeding northeast from it, the rock rises at an angle of about 5 degrees, and gradually changes into a sandstone, consisting of well-rounded, minute grains of quartz, cemented by lime and a greenish chloritic substance; in this are small lenticular sheets of limestone, though sometimes such are almost entirely absent. In the upper level of this mine, in the "black" rock, the same fault is found with the same dip to the northeast, locally with a strike north 50 degrees west. A thin bed of shale or slate here showed clearly that the throw is about 5 or 6 feet. A "chimney" enlargement of the fault fissure was exposed here, constituting a "mud opening." Near the top of the drift a horizontal crevice is traceable, along which water flowed, and which was stained red with iron. A good body of ore was found contingous to this fault on the south side."

Aside from the well-defined faults there are other evidences of disturbances in the strata. Narrow cracks and open fissures with no special trend occur; they are not continuous for any great distance and often are confined to a single ledge. These are not uneven but are sharply developed in places, partaking of the character of jointing planes. They were manifestly formed much earlier than the time of the formation of the faults themselves and before the deposition of the lead ore, for many of the crevices have become filled with galena.

From the deepest drift a large quantity of nickel and cobalt-bearing copper pyrites and galena has been mined.

Shaft No. 4.—As in the case of shafts Nos. 1 and 2, Nos. 3 and 4 are now united underground. At the latter mine operations are carried on mainly at one level, the "black" and the "white" rocks being near together, the latter rock yielding the principal product. The mine has been well developed and at present the distance from the southern to the northeastern end of the workings is approximately 1200 feet.

Faulting is even more prominent than in any of the other mines of the region. The general trend of the faults is nearly north 50 degrees west. The "main" fault of shafts Nos. 1 and 2 does not traverse the workings of No. 4. The most pronounced fault has a downthrow of 19 feet. The amount of ore is not shown to be affected through the introduction of this dislocation. As has been incidentally mentioned, the ore occurs usually in the white limestone on both sides of the faults alike.

The succession of beds at shaft No. 4 is:

Section at Shaft No. 4.

		FEET.
8.	Clay, residuary	19
7.	Limestone, dark gray, with occasional shale seams	44
6.	Limestone, dark gray, with traces of iron pyrites	7
5.	Limestone, dark gray, with traces of galena, and much iron pyrites in places	9
4.	Limestone, dark gray, with galena, and iron pyrites in varying amounts.	14
3.	Limestone, white, with galena and pyrites	27¾
2.	Limestone, white, arenaceous, with traces of galena	4½
1.	Sandstone, white	1

The principal lead-producing beds lie between 70 and 102 feet from the surface and extend almost to the light colored sandstone at the bottom. Some parts of the productive beds are very rich in the ore.

Shaft No. 5.—Work at shaft No. 5 has until recently been carried on on an extensive scale. The shaft is 137 feet deep, and the floor of the mine ranges from 128 to 145 feet lower than the surface at the mouth of the shaft. Faults are not of frequent occurrence though some of them are well developed. The

"main" fault, which appears in shafts Nos. 1 and 2, passes through mine No. 5 also. "A number of drill-holes have been sunk on both sides of it at different points and in the bed of Village creek a shattered exposure of limestone is to be seen with slickensided surfaces, which marks the line, though no prominent break can be recognized and no crevice exists there. That this fault has some influence on the distribution of the ore is doubtless true, but what this influence has been is another question. As is plainly seen in the mine the throw along it amounts to only a few feet, at least in mines Nos. 1 and 2. East of this, however, the throw amounts to much more, as is shown by the depths at which the basal sandstone is encountered in the different drill-holes. From these it would appear that the throw at some points must be at least 150 feet."

Shaft No. 6.—This mine is opened near the the old "Rattlesnake" diggings. The areal extent of the workings is approximately 2200 square yards. The depth of the shaft is 122 feet. The sequence passed through in sinking to the ore bed is as follows:

Section at Shaft No. 6.

		FEET.
9.	Clay	5⅓
8.	Limestone, yellow	7
7.	Limestone, gray, shaly	10
6.	Limestone	1½
5.	Limestone, light gray	9¼
4.	Limestone, gray, ("black"), some galena present	51½
3.	Limestone, gray, small amount of galena	1½
2.	Limestone, "white," mixed with galena	28½
1.	Limestone, white, very arenaceous	5

Diggings.—In addition to the large amount of lead ore taken from the shafts at Mine la Motte the area has also been very profitably worked for ore at and near the surface, where shallow pits and short slopes have been dug. The principal developments are the Jack, the Seed-tick, the Rattlesnake, the Wildcat, the Bluff and the Hardscramble diggings. These are scattered over a large area. Prior to about seventeen years ago, all mining which had been carried on for over a century and a half was done in these diggings.

Production.—From the time of the discovery of the deposit about the year 1720 up to 1878, the output of ore about equaled the amount that has been produced during the last decade and a half. In the latter period deep mining has been the system and work has gone on uninterruptedly. The total amount of lead produced since the beginning is over 100,000 tons.

The dressing works and furnaces are at the ends of tramways and the system of treating the ore, from the beginning until a finished product is secured, shows excellent arrangement. The degree of perfection reached in the dressing of the ore at the works is showing by the following analyses of the tailings taken from the superintendent's records:

Analyses of Tailings.

	1879	Average for year.
SiO_2	26.58	30.71
$CaCO_3$	37.93	34.80
$MgCO$	23.12	22.58
FeS	8.94	9.17
PbS	1.85	2.01
Totals	98.42	99.22

Aside from the regular output of lead there has been a large sale of nickel matte, nickel sulphide, speiss, copper sulphide and copper matte. Within the last 20 years the shipments of these alone have amounted to over $120,000.00.

Except in one case arsenic is not present in the ores, although so commonly associated with cobalt and nickel. Neither have any traces of zinc been found.

DOE RUN MINES.

Doe Run is a comparatively new mining camp. Although its development runs back scarcely a decade it is one of the most important mines in the state. Previous to ten years ago no surface diggings nor prospecting had been done. Since the original shaft was sunk many drill-holes and several shafts have been put down. At the present time the ore is being

taken chiefly from a single opening. The general sequence of the strata is well shown in shaft No. 2.

Section at Doe Run Shaft No. 2.

		Feet.
5.	Clay	11
4.	Limestone, gray	29
3.	Limestone, mixed with galena in varying amounts	65
2.	Limestone, gray, sandy	10
1.	Granite	2

The details of that portion of the section which is deemed rich enough in ore to be worked profitably are given below:

Details of Workable Ore Body.

		Inches.
8.	Limestone, yellowish, bearing galena freely disseminated	12
7.	Limestone, light grayish yellow, with a considerable amount of galena	6
6.	Limestone, dark gray, siliceous, streaked with lighter colored galena abundantly disseminated throughout	4
5.	Limestone, dark gray, clouded, in part sandy, galena disseminated and along joints especially	8
4.	Shale, with galena crystals well disseminated	½
3.	Limestone, dark gray, slaty, earthy, slightly mineral-bearing	9
2.	Limestone, dark gray, very sandy, heterogeneous texture, small amount of galena present	8
1.	Limestone, pearly white, hard, barren	13

Various diamond-drill borings have revealed many features which must be taken into consideration in prospecting and in mining. Most of the drilling in the vicinity of Doe Run has been done within a distance of one mile from the northwest corner of the sheet. The records indicate clearly a general absence of the basal sandstone, the depth to the crystalline floor, and the height above this floor that the granite bowlders occur. The distance to solid granite without regard to the topographic position of the holes ranges between a few and 200 feet. For example, a hole in which granite was reached at 21 feet down lies about 150 yards northwest of one giving granite at 262 feet, while the elevation of the shallow hole is not more than 10 feet above the other. The general plan of the mine is shown in the accompanying diagram (figure 26), in which both levels are represented.

The lower of two levels worked is the more extensive. The general direction of the slope of the limestone strata in

the workings is south 70 degrees east. The average dip is about six degrees. (See figure 20).

Few faults occur. At one point in the southern portion of the mine is a small displacement having a downthrow of

Figure 26 Plan of the Doe Run Lead Mine.

about 6 inches, decreasing to the southeast. Its strike is south 40 degrees west. The walls do not afford lead ore. In a few places along the fault there are narrow channels partly filled with clay. Faulting appears to have had but little or no influence upon the deposition of the ores and no ore is found along the walls of the faults. The disturbances, other than those marked by the sharp cracks and crevices

filled with ore, appear to have taken place after the ore was deposited. The individual cracks are often confined to a single stratum and have no apparent relation to one another.

The total output to date has been over 21,000 tons. Since 1891 the Flat River mines have been opened and the ore has been treated at Doe Run, the amount being 35,000 tons.

The system of handling the ore is very complete, from the time the contents of the cars from the mines are dumped at the crushers until the roasted product is taken from the furnace. The product from the mill is about 75 per cent galena, the remainder pyrites and chat. The roast analyses 70 per cent lead, 15 per cent silica, 4 per cent sulphur and 6 per cent iron. The other constituents are lime, magnesia, alumina and water. The silica mentioned is added just before the roast is removed, in order to "cinder" the mass and facilitate fusion. This sand is especially well adapted to this use. It is fine-grained and 97 per cent pure. From eight to ten thousand pounds of roasted ore are drawn off in twenty-four hours from each of the four furnaces. The dressing works are run continuously, handling the ore from the Doe Run shaft as well as from the company's shaft at Flat River, which lies about seven miles northward on the Mississippi River and Bonne Terre railway.

EINSTEIN MINE.

The Einstein mine is of special interest for the reason that it is the only example in the state or in the Mississippi valley of a fissure vein. The place is commonly known as the Silver mines. It is located eight miles directly west of Fredericktown on the St. Francois river (Tp. 33 N., R. V E., Sec. 12, SE. ¼ of SW. qr.). As its importance is on account of the silver ore found it will be considered more at length in another place. The silver is contained in galena. But little has been done to operate for the lead.

MINOR WORKINGS AND PROSPECT HOLES.

In the neighborhood of Fredericktown considerable prospecting has been done and some ore taken out. Nifong and Browin had a shaft sunk in the vicinity of the town. The

depth reached was 61 feet, at which point sandstone was reached. Toward the bottom of the shaft the limestone was found to be mineral-bearing and a considerable amount of iron pyrites, copper pyrites and galena was taken out. The lead ore was distributed through the sulphides of iron and copper. There was no regular stratum in which these ores were evenly disseminated. They occurred in thin streaks with occasional concentrated masses. The ores were not analyzed so that the presence of nickel and cobalt was not detected.

Three miles west of Fredericktown the Fox mine was formerly operated (Tp. 33 N., R. VI E., Sec. 12). The shaft was 50 feet deep, with lead ore disseminated through a vertical thickness of twenty feet at the bottom, the lower third being quite rich. Other shafts have been reported as put down in this neighborhood. There is now no signs of mining. An analysis of the Fox mine product showed that copper, nickel and cobalt were present in small amounts. The country rock is described as a subcrystalline, bluish gray limestone with many cavities.

The Schulte drill-holes were put down three miles northwest of the town (Tp. 33 N., R. VI E., Sec. 1, NW. qr.). In some of them a considerable amount of galena was discovered. Hole No. 1 lies on the west side of the hill in a shallow ravine. The strata passed through are as follows:

Schulte Drill Hole No. 1.

		FEET.
3.	Clay	10
2.	Limestone, gray, with one foot galena-bearing, five feet from lower edge,	50
1	Granite, solid, red	1

In drill-hole No. 15 galena was found at forty-nine and at eighty-four feet from the surface. Sandstone was reached 109 feet down. Similar occurrences of lead ore were noticed in holes numbers 3, 8, 15, 17, 24, 25, 31, and in some others. Northeast of Fredericktown lead has been found at a number of points along Village creek.

The hard, subcrystalline, light to dark gray and buff limestone crops out in the hillsides and along many of the streams

in the northeastern quarter of the sheet, but no special efforts have been made to ascertain whether or not these heavy magnesian ledges are lead-bearing. A few pits have been put down to a depth of perhaps ten feet. In some cases the rock thrown out of these shallow pits contained small specks of galena, and such is the case in some of the heavy surface ledges, especially near Libertyville. Other localities are reported as exhibiting galena, and "float" mineral is very commonly reported as having been found.

IRON DEPOSITS.

Although practically no iron mining is now carried on within the boundaries of the sheet the deposits of ores are both valuable and numerous. The principal ores are hematite and limonite.

Hematite.—The hematite is confined to those areas in which granite and porphyry is the country rock. It occurs in narrow veins or small horizontal beds. No deposits are worked in the district.

Five miles southwest of Fredericktown, on the flanks of Matthews mountain specular ore has been found, and also a couple of miles northeast of the Silver mines. Two miles northwest of Skrainka a narrow vein in red granite occurs on the old Miller place (Tp. 34 N, R. VI E, Sec. 29). Veins also occur in the vicinity of the Silver mines.

Limonite.—As the chief ore of iron occurring in the area it is found in beds of greater or less thickness, usually mingled with chert fragments. Southwest of Fredericktown on Matthews mountain, the ore is quite abundant in places, both within the limits of the sheet and just beyond. It occurs in the form of large rounded bowlders and fragments and is covered by a thick layer of detrital material, principally angular porphyry fragments and limonite masses. A number of shallow pits have been excavated.

The principal point where the ores have been mined recently is on the Mine la Motte estate, where they are used as a flux in lead smelting. In 1890, between 300 and 400 tons were

taken out for this purpose. At the present time about 600 tons are used at the smelters, most of the ore coming from near Cornwall, just beyond the eastern limits of the sheet and other neighboring localities. Much of the limonite taken from the LaMotte tract is from a place directly east of the town near the top of a chert hill.

COPPER DEPOSITS.

While comparatively little copper is now taken out within the limits of the sheet important deposits occur. These were formerly worked to a greater or less extent. They are confined chiefly to the southern half of the sheet. The principal ores are chalcopyrite and malachite. They are usually associated with the sulphides of cobalt, nickel, iron and lead.

In the Mine la Motte tract considerable copper ore has been obtained. At the old Jack diggings a strip 70 feet wide was encountered which carried copper sulphide with a considerable amount of nickel. In cutting the entries along the lead-bearing horizon, it was found that while there was no sharp line of division between the lead and the copper ores, the change from one to the other was very abrupt. Within a very few feet the galena was entirely replaced by the copper ore.

In shaft No. 2, on the lowest level, there occurs in a shallow depression immediately beneath the lead-bearing stratum a considerable body of copper ore along with some nickel and cobalt. The other mines on the estate also contain some copper ore. At the LaMotte mines, however, little attention has been given to the mining of copper pyrites, though some shipments have been made of both the ore and copper matte, the value of two lots being over $600. As the ore is found closely associated with those of lead, nickel and cobalt, it undergoes severe treatment. The matte formed of the latter two and the copper has been an important product from the works for over 20 years.

The extreme southwestern portion of the Mine la Motte tract (Tp. 33 N., R. VI E., Sec. 1, NW. qr.) contains the Old Copper mines. Mining was first prosecuted for copper, though

unprofitably. Tunnels were driven into the northern slope of the hill. More recently, shafts have been put down and mining for lead successfully carried on.

In the neighborhood of Fredericktown copper has been mined at several points. Northeast of the town about two miles, near Village creek, some ore has been taken out near the location of the old Gasney lead mine.

Southeast of Fredericktown are several localities where important deposits occur. The Buckeye copper mine (Tp. 33 N., R. VII E., Sec. 16, NW. ¼ of SW. qr.) is the principal opening, and was worked for some time. This shaft was sunk about forty years ago. The rock passed through is a light gray subcrystalline magnesian limestone through the whole thickness of which are disseminated in greater or less amounts ores of cobalt, nickel, copper, lead and iron. The workable deposits were forty and eighty-five feet deep, and at these depths levels were established and drifts worked. At the lower level the drift was extended sixty feet to the southeast and an equal distance to the northwest of the shaft. The various ores occurred intermixed, filling cavities and narrow crevices within the hard limestone, often giving to the ledge a becciated appearance. The pyrites, especially that of iron, is finely crystallized. The copper ore usually occurs in narrow veins. Around the shaft great heaps of practically lean rock are piled up, and today the surface material upon these dumps is altered and on the limestone fragments there is a coating of the green carbonate of copper. This covering is sometimes as much as one-eighth of an inch thick, showing that the limestone contained much copper pyrites. The lead ore is said to have contained a considerable percentage of silver. Two years ago a drill-hole was put down at a level nearly corresponding to that of the mouth of the shaft. The depth reached was 125 feet and the ores of copper, nickel, cobalt, lead and iron were encountered at frequent though irregular intervals. An effort was also made to clean out the shaft, but this proved a failure. In recent years the mine has been abandoned entirely. Judging from the surface materials and the reports current concerning the deposit,

it would seem that there is an abundance of ore. The rarer metals were shipped to Europe.

Between Fredericktown and Cornwall copper has been taken out from surface pits excavated in the detrital material overlying the magnesian limestone. Both the common ores were present. Several thousand pounds were taken out at one time. Five miles southwest of first named town, at the foot of Matthews mountain, a number of pits have been put down for ore; and on the opposite side of the mountain, just outside the sheet, ore has also been taken out at several points. Copper has also been obtained two miles northwest of the Silver mines on the St. Francois river.

MANGANESE.

Although wad, or the black oxide of manganese, is of rather common occurrence in southeast Missouri associated with the deposits of specular iron, and in residuary cherts and clays resting upon the sedimentary beds, few systematic attempts have been made to mine it within the limits of the area under consideration. The nearest locality where it has been taken out in commercial quantities is several miles west of the sheet. This locality is on Culbertson mountain, five miles south of Ironton, in Iron county. At this point a large amount of ore has been mined and shipped, but for a number of years little work has been done. Within the Mine la Motte sheet a great many deposits have been discovered, but thus far few attempts have been made to develop them extensively. The main deposits of the ore are two to three miles northwest of the Fredericktown (Tp. 33 N., R. VI E., Secs. 1, 2, 11 and 12). Some places show that the ore bed extends continuously over several acres. In the southwest quarter of section 11 a number of pits were excavated along the eastern slope of the hills, east and south of the two county roads in which wad was met with. Several of the pits, though only a few feet deep, contained ore which continued to the bottom. It appears abundantly scattered through a very silicious residuary clay and rests on an impure, rather coarse-grained sandstone. The quality is

somewhat inferior and much of it is mixed with oxide of iron. Freshly fractured fragments are quite hard, and steel gray to black in color. In the northern half of section 12 (Tp. 33 N., R. VI E.) and on adjacent land to the north and east, wad is frequently encountered. On the roadside, eastward from the intersection of the county roads, a few feet of a low grade of ore is exposed for some distance. Northward, in a field and in the bank of a small branch, similar occurrences are common. Shallow prospecting pits were put down and in every case the ore extended several feet from the surface. Usually, the character of the bog ore is poor, but some higher grade deposits, which may prove extensive upon development, are also present. In section 2 beds of manganese which crop out near a small branch have been found to underlie an area of considerable extent. Much of the ore here is the earthy, black variety and is tolerably free from impurities.

Southeast of the last named locality, in the northwest quarter of section 1, the diamond-drill in prospecting for galena passed through a manganese bed at a number of points. In the surface clays, which overlie the indurated rocks, manganese was found at depths varying from 30 to 60 feet; some layers were a foot thick, besides many thin seams. The quality of the manganese is superior to that known to exist elsewhere within the limits of the sheet. It is of a steel-gray color, with metallic to brilliant lustre. In the samples collected no impurities could be detected and it should be classed as a very high grade ore. It is doubtless suitable for both speigeleisen and ferro-manganese. Very little silica can be detected and the percentage of iron is low.

Seven to eight miles south of Fredericktown at a point just beyond the boundary of the sheet there is another deposit of manganese quite different in character from those already described. This is a decidedly black earthy variety. Macroscopically it appears pure, except for a few fine quartz grains.

Other deposits occur at numerous points and fragments of the common bog ore are frequently noticed on the slopes of the chert hills.

NICKEL AND COBALT.

The paragenesis of nickel and cobalt ore is very intimate. Both minerals are closely associated with the ores of iron, copper and lead. The common occurrence is the black earthy cobalt or asbolite which usually contains from one to five per cent of nickel, and massive linnæite which also carries some nickel. An analysis of the galena from the Old Copper mines in the southwestern corner of the Mine la Motte tract gave Chauvenet 1.68 per cent of nickel and 0 63 per cent of cobalt. The lead ore from the Neidner shaft on the estate gave the same analyst:

	Per cent.
Lead (metallic)	65.53
Copper	Trace
Nickel	4 26
Cobalt	1 42

The nickel ore from the Jack diggings showed 2.27 per cent of the metal and 1.66 per cent of cobalt.

In this connection it is of considerable interest to learn that nickel as well as manganese occurs in appreciable quantities in the massive crystallines of the region. Analyses, by Melville, of a fine-grained granite (I), and two porphyries (II and III) from a locality (Tp. 33 N., R. V E., Sec. 5) three miles northwest of Silver mines, but just outside of the boundaries of the sheet, gave the following results:

Table of Nickel Determinations of Missouri Granites.

	I.	II.	III.
Loss at 100 C	0.22	0.12	0.17
Loss on ignition	0.54	0.30	0.26
SiO_2	72.35	71.33	71.88
Al_2O_3	13 78	12.55	12.88
Fe_2O_3	1.87	3.75	3.05
FeO	0.36	0.85	1.05
NiO	0.20	0.15	0 02
MnO	0.06	0.04	Trace
CaO	0.87	0.94	1.13
MgO	0.42	0.58	0.33
K_2O	4.49	4.20	4.46
Na_2O	4.14	4.52	4.21
P_2O_5	0.13	0.16	0.15
TiO_2	0.44	0.55	0.22
Totals	99.87	100.04	99.81

Comparatively little attention, however, has been paid to the mining of the ores alone and what has been shipped has been mined in connection with lead. Yet the product obtained is not unimportant. At Mine la Motte alone the output of speiss for the last twenty years has amounted to over 570,000 pounds, that of matte 827,000 pounds, and of nickel sulphide 36,000 pounds. The amount taken from the Old Copper mines is not known with exactness, but it appears sufficient to make a total of all the the cobalt and nickel products something like 710 short tons. As the mining of the minerals is commonly a secondary matter much of the material is not cared for.

SILVER.

The occurrence of silver within the limits of the Mine la Motte area is of unusual interest from the fact that nowhere else in the state have deposits of like character been found.

The metal is found in true quartz-filled fissure veins, a considerable number of which exist in the region. The largest is located on the St. Francois river about eight miles directly west of Fredericktown (Tp. 33 N., R. V E., Sec. 12, SE. ¼ of SW. qr.) at a place now known as the Einstein Silver mine.

The rock, for a considerable distance around the locality, is a coarse-grained, red, biotite granite, or granitite, a part of the great central field. It is cut by dikes of diabase and by quartz veins, the largest of which is about four feet in thickness. The locality has manifestly been the seat of considerable disturbance, as is indicated by the great number of fissures. The fact that some have been filled with the basic rock material, and some with other vein stuffs, clearly shows that the formation of the two sets did not take place at the same time. The general trend of the diabase or greenstone dikes is nearly in a north and south direction; while that of the quartz veins is a little south of west. The former are nearly vertical; the latter dip to the southeastward about 60 degrees.

The locality is unique in furnishing, besides silver-bearing galena, a number of minerals which are found nowhere else in the state. The vein-stuffs are of such peculiar kinds and the wall-rock has been so altered for a distance of several feet that it is quite manifest that fumarole action has been vigorous. A large amount of micaceous material which may be regarded as sericite, has been produced. Associated with it are other minerals usually not met with, and these are also scattered through the gangue, which is largely quartz, and the argentiferous galena. The feldspar in the wall-rock has been almost completely changed to the sericite, which occurs in fibrous masses. A dark lithia mica, zinnwaldite, occurs; also topaz, fluorite and wolframite. The amount of silver contained in galena varies greatly. In some cases as high as 300 ounces to the ton are reported; in others scarcely a trace. The average of 50 assays was about 46 ounces to the ton.

The plan of the mine is shown in the accompanying cut (figure 27), which is taken from surveys conducted by W. B. Potter.

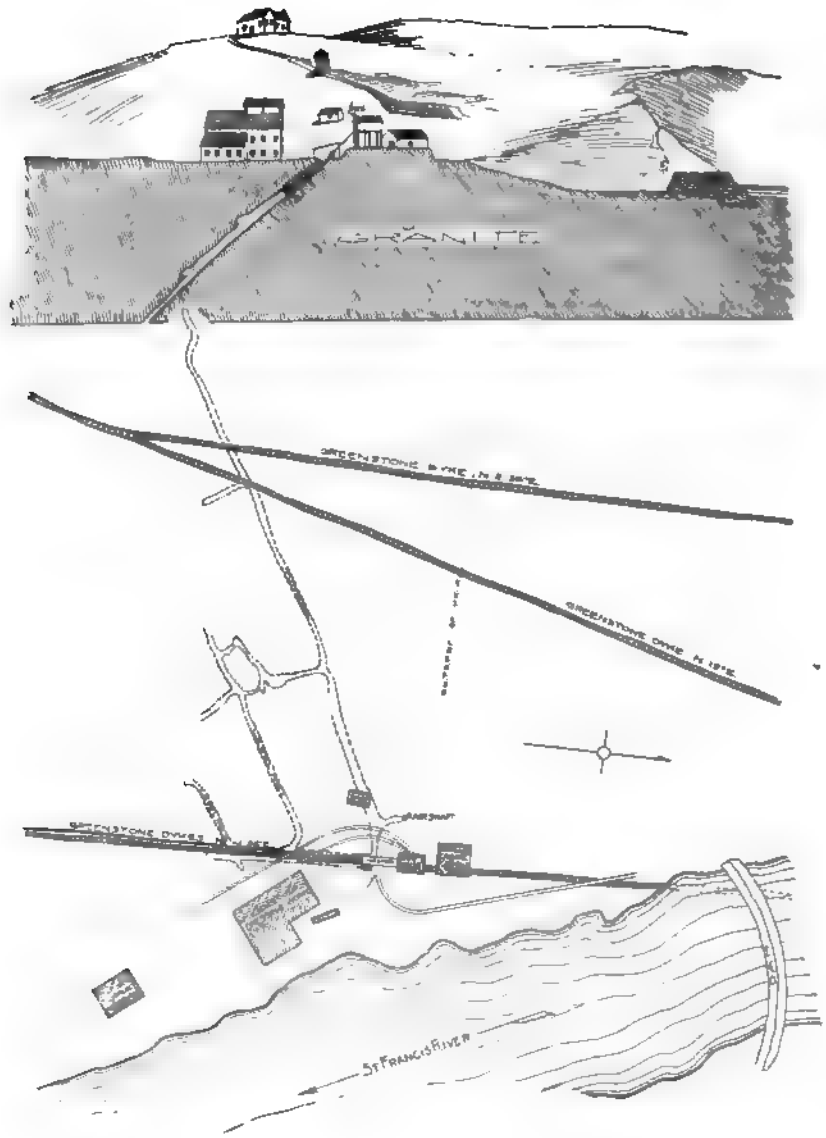


FIGURE 27 Plan and Cross-section of the Einstein Silver Mine

The place on which the Silver mine was opened was entered as mineral land in 1855 by one Beaugholtz, who prospected for several years and finally sold out to Knox and Einstein of St. Louis. Systematic prospecting was begun in 1877; and as a result a quartz vein was discovered about 100 feet above the St. Francois river. The dip having been carefully determined, a tunnel was started near the water level and driven in for a distance of 200 feet. An incline of 180 feet was also put down, from the bottom of which two or three drifts were started. Two years later the Einstein Silver Mining Company was formed and the work pushed vigorously. A large stone dam was constructed to furnish power, and furnaces and smelting works were built. Through some mismanagement the company was obliged to give up work. For a long time the mine has been idle, but recently another attempt has been made to develop the ore and a new shaft has been commenced.

Altogether 50 tons of lead were taken out of the Einstein mine and about 3000 ounces of silver.

BUILDING STONES.

No other district of similar size within the limits of the state, or perhaps in the whole Mississippi valley, has a greater variety of good stone for all kinds of constructional purposes than the area occupied by the Mine la Motte sheet. For quantity, quality and beauty, the stones that can be used for building and ornamental work are unsurpassed by any in the United States. This is attested by the fact that the stones from this, or the neighboring localities, have entered largely into the construction of some of the largest and most massive buildings in the country. Leading structures in Dallas (Texas), Omaha, St. Louis, Des Moines, Minneapolis, New Orleans, Chicago, Indianapolis, Cincinnati, Cleveland, Baltimore and other large cities have been erected wholly or in part of the Missouri stone. This stone has been transported a thousand miles for buildings reared upon the very brink of quarries the product of which is known the whole country over.

There are in the district four general classes of rock that are suitable and available for building stone. These, with their chief varieties which will be described farther on, are as follows:

I. Granite.
   1. Granite (biotite granite, or granitite).
   2. Syenite (granite-syenite).
   3. Black granite (diabase, "greenstone").
   4. Porphyry ("felsite").

II. Marble.

III. Limestone.
   Dolomite.
   Ordinary limestone.

IV. Sandstone.

GRANITES.

Under the general term "granites" all the massive crystalline rocks of the region are known. Lithologically there are several distinct varieties which have very different properties, and which have, moreover, very different composition and structure. These various features have an important influence in the selection of a stone for structural materials.

Granite.—The coarse-grained granite composes by far the greater portion of the crystallines in the district under consideration. Its area is not far from 50 square miles, most of which is easily accessible for quarrying. In color the stone is a warm red to pink; in places merging into gray. Though usually a coarse-grained rock, fine-grained varieties are of frequent occurrence. The arrangement of the constituent minerals give very beautiful effects of contrast. (Plate xii, photograph of polished surface.) The granites take a very high polish. All are very strong and are very durable. Extended examinations in thin slices under the microscope clearly indicate that the rock is in a remarkable degree free from objectionable constituents. Both chemical and field investigations corroborate these observations. The rocks consist almost wholly of a granular aggregate of quartz and feldspar. White

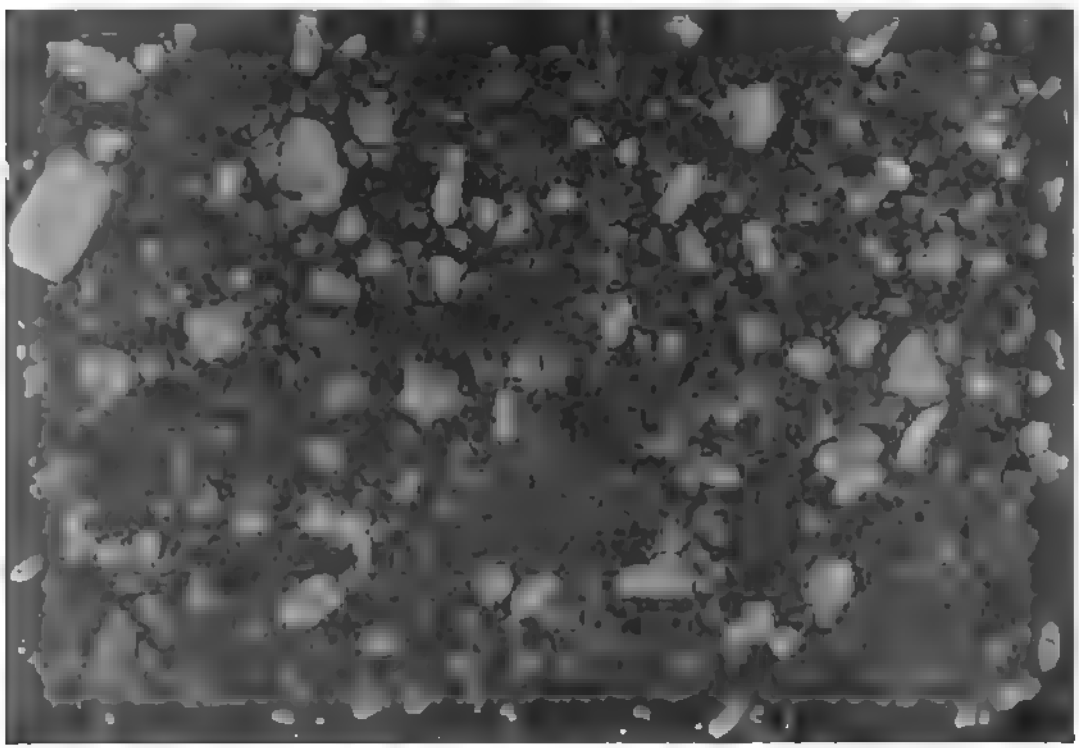
mica (muscovite) is entirely absent. The amount of black mica present (biotite) which is usually one of three essential constituents and a mineral which is the first of the principal components in most granites to break down under meteoric influences, is reduced to a minimum amount and in many cases is almost entirely absent. The feldspar is, for the most part, orthoclase, the most durable of the feldspathic minerals. Accessory components liable to decompose are wanting. The great preponderance of the more indestructible constituents is also indicated by the chemical analyses.

Analyses of Granite.

	I.	II	III.
Loss at 100 C	0.14	0.22	
Loss on ignition	0.68	0 54	
Silica, SiO_2	69.94	72.85	73.98
Alumina, Al_2O_3	15.19	13.76	14 32
Iron, ferric, Fe_2O_3	1.69	1.97	
Iron, ferrous, FeO	0.69	0.86	
Nickel, NiO		0 30	
Manganese, MnO	0.08	0.08	
Lime, CaO	1.15	0.87	1.04
Magnesia, MgO	0 92	0.42	
Potash, K_2O	4.29	4.49	3.32
Soda, Na_2O	3 95	4 14	4 56
Phosphorus, P_2O_5	0.13	0.13	
Titanium, TiO_2	0.25	0.44	
Totals	99.32	99 87	

The first two by Melville are from samples taken three miles northwest of the Silver mine, but just outside of the boundaries of the sheet. The third by the St. Louis Sampling and Testing Works, is southeast of the other locality and about two miles west of the Silver mine.

As a quarry rock the granite has a number of features recommending it. It is jointed in such a way as to make quarrying both easy and economical. The proximity of the fractures varies at different points. In places the breaks are



PORPHYRITIC GRANITE, POLISHED SURFACE

close enough together to permit paving blocks being taken out with the greatest facility; in others monoliths of any size may be obtained perfectly free from seams and defects. The stones are readily split in quarrying and easily dressed in preparing them for the purposes for which they are designed. Furthermore very little "stripping" is required in obtaining access to the stone. The general aspect in the quarry ledge is shown in plate xiii, which represents the Milne and Gordon quarries.

Syenite.—The rock to which this name is usually applied in the region is a "blue" granite, in contradistinction with the gray or red granite. It is properly a syenite-granite. In texture and other physical properties it is nearly the same as the red variety. Minerallogically, however, it differs from the ordinary granite in containing hornblende and much more black mica. It contains the least quartz of any granitic rock in the region. The blue color is imparted chiefly by the biotite and hornblende, though the feldspar also has a peculiar bluish color.

There are several square miles of this variety of granite lying southwest of Syenite and Knob Lick, all of which is easily accessible. The stone takes a brilliant polish but it is necessary to exercise some care in selecting the rock for dimension work, as often small seams are present which renders fracturing easy. This would, however, doubtless be largely overcome by the adoption of better methods of quarrying.

Black Granite. — The black granites are greenstones, or diabases. They occur in dikes and small circular areas cutting the granite and porphyry. In color they are very dark green or gray and present a marked contrast to the rocks associated with them. They are heavy, very tough, and when struck with the hammer emit a metallic ring. The diabases admit of a fine polish. Owing to peculiarities of mineralogical composition these rocks do not make durable building materials and should not enter into expensive constructions. Even if they were durable little good dimension stone could seldom be obtained on account of the numerous seams present.

For paving blocks the diabase rocks are unsurpassed, and should be used to the greatest extent possible in those districts of the cities in which the heaviest traffic is carried on. While doubtless good for one-half to three-quarters of a century the atmospheric decay of the blocks is just rapid enough to prevent them from becoming slippery which is so objectionable in granite and quartzite blocks.

Porphyry.—The "felsite" as it is commonly called locally is abundantly and widely distributed. It is a very close-grained, often almost glassy rock having a variety of colors, pink, red, purple, green, brown and black in many shades. It takes a brilliant polish. The rock is extremely hard and flinty, rather brittle and breaks, with a somewhat conchoidal fracture. On account of the difficulty in working and dressing, the porphyry is not very well suited for dimension work.

QUARRIES IN GRANITE.

Allen & Vieth Quarry.—The location of the quarry of Allen & Veith is about four miles northwest of Knob Lick and one-half mile north of Doe Run creek (Tp. 35 N., R. V E., Sec. 36, SW. qr). The working face is 180 feet long; the depth of the quarry averages twenty feet. Numerous joints, running mainly in a NE–SW direction, are noticeable. They are not, however, so frequent as to prevent getting out blocks of any desired dimensions. The stone has been worked up chiefly into pavers, half a million having been taken out. The stone is of a clear red color and dresses readily. Its composition differs somewhat from that at most of the other quarries, quartz being abundant. A vertical quartz vein traverses the bed. One large steam derrick has been employed and tracks laid to the dumps. It is one of the largest block quarries in the area.

Kirk Quarry.—A short distance from the Allen & Vieth opening is a quarry on the south slope of the hill (Tp. 35 N., R. V E, Sec. 35, SE. qr). Quarring was done in solid red granite which is of medium grain and dresses readily. The product is pavers, of which 23,000 blocks have been taken out.

Chamberlain Quarry.—Not very far away, on the Peers land, a granite quarry has been opened, from which about 38,000 blocks for streets have been taken. It now has a vertical face twenty feet high which could be easily extended. The rock is rather fine-grained, but works easily and could be utilized for dimension stone as joint planes are not frequent.

A dozen or more other openings have been made in the same vicinity. They lie on both sides of the Doe Run creek. A couple of miles farther up the stream (Sections 27 and 28) granite has also been quarried at several points.

Eaves & Crawford Quarries.—The principal openings of those last mentioned are located on the east side of the creek (Tp. 35 N., R. V E., Sec. 27, SW. qr.) The immediate exposure of granite is quite small. Over 3,000 blocks have been taken out.

Near the mouth of Doe Run creek on the flank of a prominent hill northeast of Wachita mountian considerable stone has been obtained.

Cartee Quarry.—Work at this place has been carried on (Tp. 34 N., R. V E., Sec. 2, NE. qr.) in granite for about eight years. There are several small quarries. Blocks are also obtained from surface ledges. The red granite is coarse in texture. About 60,000 blocks have been hauled to the railroad. At the present time there are no extensive operations being conducted.

Wood Quarry.—This quarry is on the Taylor land, on the north hillside about one-fourth mile west of the Cartee place. The rock is quite similar and the same kind of methods are employed in quarrying and dressing the rock. Over 32,000 blocks have been produced.

Eaves Quarry.—Northeast of the last mentioned openings is operated a small quarry (Tp. 34 N., R. V E., Sec. 1, NW. qr.) from which several thousand blocks have been removed. The granite is the ordinary light red, medium-grained variety. No heavy blasting has been undertaken, the top ledge of granite alone being utilized, since at the surface the rock is fresh and very durable.

Wildcat Quarry.—This quarry is at the top of a broad granite hill (Tp. 34 N., R. V E., Sec. 13, SE. qr). The rock is tolerably coarse-grained, pale red in color and works easily. No dimension stone has been taken out, although joint planes are not so abundant as to interfere with the quarrying of large blocks. About 50,000 six- and eight-inch paving blocks have been made here. The granite in this district is all of splendid quality. It seems to be more uniform in color as well as in texture.

Berry Quarry.—Three miles northwest of Knob Lick are several large quarries (Tp. 35 N., R. VI E., Sec. 30, SE. qr). A switch connects them with the Belmont branch of the I. M., St. L. & S. railroad, a little over one mile distant. Until recently it was owned and operated by the St. Louis Granite Company and went by the name of the O'Meara quarry. The quarry was opened up a little more than four years ago on the northeast slope of a hill which is partly covered by sandstone. It has a circular face of about 300 feet in length and averages fifteen feet in depth. Across the center, nearly east and west, a seven-foot channel has been excavated to enable work to be carried on more easily. The quarry as a whole is in excellent working condition. Usually the amount of stripping is slight. On the northeast side the rock is somewhat decomposed and is not utilized, but elsewhere it is very firm. In texture it is of perhaps the coarsest of any within the area. Some pink feldspar crystals are found more than an inch in length. It works readily, especially on the lift, and blocks of any desired dimensions can be taken out. The plant consists of a rack and power shed and a number of dwellings; also a drill, derrick, traveler, and a "Jenny Lind" polisher for flat surfaces; the machinery is worked altogether by steam power. The dimension rock has been used in the construction of the Bissell Point waterworks building, pump house at Chain of Rocks, for tops of piers for the elevated railroad in East St. Louis, Illinois, and for many other structures. In addition half a million blocks for street paving have been taken out.

JOINTING OF GRANITE, MILNE AND GORDON QUARRY AT SYENITE.

Tetley Quarry.—About 200 yards south of the Berry quarry is an opening on the Tetley land. The work is a reddish gray granite, and rather coarse-grained. About 50,000 paving blocks have been used from this place.

Steffen Quarry.—A couple of small openings have been recently started, one on the north and the other on the south side of the O'Meara switch, just west of its connection with the Belmont branch railroad (Tp. 35 N., R. VI E., Sec. 29, SW. qr). As quarrying has just been begun only a few blocks have as yet been made. The granite is the coarse, grayish red variety, is easily trimmed and is doubtless quite a valuable stone. Drilling is done by steam power and the intention is to open up large block quarries. Sandstone extends over the top of the hill along the north face of which the granite is uncovered and quarried.

West of Knob Lick around the town of Syenite are the most important quarries in the sheet. Three long switches leave the Belmont branch of the Iron Mountain railway at the station to provide shipping facilities for the output.

Meyers Quarry is situated just north of the county road, one-half mile west of Knob Lick. It was opened two years ago and block-making has been prosecuted most of the time since. Probably 50,000 six-inch and eight-inch blocks have been produced. The rock worked is called "blue syenite". It is a gray granite with rather medium texture. The jointing planes are rather numerous, the general direction being southwest-northeast. The stone is admirable for paving purposes and could be used for certain dimension work. There are, however, small spots of dark gray material scattered through the mass. These of course detract from the value of the rock for building purposes but does not lessen its value for paving blocks. The large masses are raised to the surface by a hand derrick.

Flemming Quarry.—This opening lies about 100 yards west of the one just described. It was first opened three years ago. The rock is the ordinary "blue" granite, and is very easily worked on the rift. Something over 55,000 blocks have been made.

Asplos Quarry.— Northeast of the Flemming opening is a small quarry in the "blue" granite, such as is found at the other quarries in the vicinity. It dresses easily and joints are sufficiently numerous to aid very materially in the quarry operations. About 10,000 blocks have been hammered out.

McGeorge (J.) Quarry.— The J. McGeorge quarry was opened 11 years ago and a large quantity of paving blocks have been obtained. The working face is about 20 feet high and 150 feet long. It is opened just north of the road about half-way between Knob Lick and Syenite, in the "blue" granite. Over the hard rock are two to six feet of decomposed granite and residual clays which must be stripped. Joint planes run a little west of south. This has been one of the most important workings. A single hand-power derrick is used in raising the large masses to the surface.

McGeorge (W.) Quarry.—This opening lies just northwest of the J. McGeorge quarry. Operations were begun 13 years ago and a large number of blocks made. It is 20 feet in depth and has an average of five feet of stripping. The joints almost invariably lie nearly north and south.

Kelly Quarry.—At the Kelly quarry about a quarter of a mile north of the J. McGeorge place considerable work has been done. It is in the coarse-grained "blue" granite, upon which rests from four to eight feet of stripping.

In and around Syenite is the largest development of the quarry industry within the limits of the area.

Milne & Gordon Quarry.—The quarry and dressing works are at Syenite, just north of the county road, in the center of section 5 (Tp. 34 N., R. VI E.). It is one of the oldest granite openings in the district. The worked out area is about thirty feet deep, but at the present time the work is being done at a twenty-foot bench. A good face of rather coarse-grained red granite has been developed. At the southeast corner of the opening the stone is grayer and is here traversed by red porphyritic streaks. A few feet southeastward, beyond the quarry proper a coarsely crystalline gray granite lies above the red. It is of firm texture and suitable for dimension stone.

This area is included in the regular quarry. The joints are sufficiently numerous to greatly facilitate the work. The general direction is about south 10 degrees west. The texture is fairly coarse but the color is not constant over large areas. There is a tram-way from the quarry to the railroad just above Knob Lick. The plant itself has in addition, three steam and two hand derricks at the quarry and one hand derrick at the railroad; also vertical and circular polishers, sheds, and other necessary equipment. The output from the quarry has been mostly dimension stone for large structures in various cities, chiefly St. Louis, and for monuments. The stone appears to good advantage in the roughly dressed state and partakes of a very bright polish. Blocks of almost any desirable dimensions can be secured. One huge monolith was broken out that was 50 feet long, and 20 feet in width and depth.

Syenite Quarries.—The Syenite Company was among the earlier operators in the region. Work was begun in 1880, large sheds erected and machinery put in for handling the blocks. Later the work was transferred to Graniteville in Iron county. Two principal quarries were developed to some extent before the change was made. One lies above the Little St. Francois river north of Syenite. This was the principal seat of work and was about fifty feet deep. It is estimated that 175,000 cubic feet of granite were quarried. The stone is of a grayish red color and of medium grain. The general trend of the master joints is in a direction a little west of south; of the secondary planes nearly at right angles to these. The other main quarry lies about 150 yards northwest of the Milne & Gordon quarry. It has a twenty-foot perpendicular face. Joint planes are not so numerous and large blocks are obtained. The texture is a little coarse but the stone works very easily. The company has another quarry in granite north of the large one. Only blocks were made here. A switch leaves the railroad north of Knob Lick and extends to the old work sheds. Although now abandoned there is much probability that work will be resumed here instead of continuing at Graniteville.

Ratcliffe Quarry.—This is a small quarry west of Syenite. The grayish red granite used is quite coarse-grained, but there are not enough joint planes present to enable the work to be carried on without some difficulty. Probably 12,000 blocks for paving have been made at this place.

Ward & O'Bannon Quarry.—This is a new locality just east of the Ratcliffe. Two to three thousand blocks have been made. The stone has but few joints, but works on the lift with ease. No stripping is required as yet.

Arnold Quarry.—The Arnold quarry, to the south of the county road on the Baker land in the southwest quarter of section 5, has been opened three years. In this time 17,000 blocks have been obtained. The opening is in a red granite, tolerably coarse textured.

Milne & Gordon Leased Quarry.—This is also on the Baker land. It was opened up for block-making purposes eight years ago and quite an extensive excavation has been made. The granite is light red in color, and medium-grained. Besides the masses which are broken into pavers a considerable amount has been used in the construction of bridges along the railroad.

Wood Quarry.—Formerly the Rucking & Eistrup quarry. The opening is in the red granite, on the lower part of Knob Lick mountain about three-fourths of a mile nearly west of the highest point. The rock is considerably jointed and paving blocks are made with but little difficulty. A derrick is employed for shifting the large masses.

Cross Quarry.—Work began at this point, which is on the northwest slope of Knob Lick mountain, in 1894, and since that time, 40,000 blocks have been taken out. The stone is the ordinary light grayish red granite and has an easy fracture.

Allen Quarry.—This place is also opened on the northwestern part of Knob Lick mountain. The stone is reddish gray. Over 175,000 blocks have been shipped out. The stone works well and makes an excellent paver.

Wallace Quarry, formerly the old Welch quarry, is situated high up on the northwest side of Knob Lick mountain. It is 250 feet long and 100 feet wide; and has been worked for

a dozen or more years. The quarry is eight to eighteen feet deep, with two to six feet of stripping. The fracture is more certain on the rift parallel to the north and south planes. In the upper part of the quarry a porphyritic rock appears, at one point being eight feet thick. Nearly 1,000,000 blocks have been made here.

Wells Quarry.—A short distance on the slope to the northeast from the Wallace quarry is another recently opened. The color of the granite is the usual reddish gray and the texture is tolerably coarse.

Pritchett Quarry.—Work was begun just northwest of Wells quarry in the spring of 1895. The granite here is of a lighter color than at the Wallace but otherwise is quite similar. Only a few blocks have as yet been removed.

Summers Quarry.—This is quite a large opening, situated in Tp. 34 N., R. VI E., Sec. 9, NW. qr. It was opened about ten years ago and quarrying was carried on interruptedly until recently. The excavation is about 150 feet in length. The stripping of decomposed materials is from five inches to as many feet thick. There are many joint planes trending nearly east and west and north and south, but these do not interfere with the adaptability of the stone for dimension purposes. The easiest way for working the granite is on the rift, yet the "hardway" is often resorted to. The "hardway" is nearly perpendicular to the direction of the slope.

Simpson & Thurley Quarry.—What is known as the main Simpson quarry lies about 500 feet south of the Summers place, and there is another about 250 feet to the northeast. The latter is in light pink to gray granite; the former in a red variety. Both are now abandoned by the blockmakers, but the debris, consisting of chips and large blocks which have accumulated, are transported in cars along a tramway to the railroad at Knob Lick and shipped as grout to St. Louis where it is crushed and used in the preparation of granitoid walks. A very large number of blocks were manufactured from the two localities.

Anderson Quarry.—This place was opened about four years ago on the hillside seventy-five yards southeast of the Summers quarry. It is now only about thirty by forty feet in areal extent and ten feet deep. It has been idle until recently, but block-making has been resumed. The granite is fairly coarse-grained.

Butler Quarry.—The old Butler openings lie on the south side of Butler hill, a western extension of Knob Lick mountain. There are in this place a number of surface quarries known as "bowlder motions," the solid beds not having been reached. Some of these detached masses are twenty feet or more in diameter and are composed of fine, undecayed granite. Only one or two excavations are being worked at present, but in past years the output has been quite large. Most of the granite is rather coarse-grained and of a grayish red color.

Wood & Hibbits Quarry.—In the northeast quarter of section 7 (Tp. 34 N., R. VI E.), quarrying has been going on in a tolerably fine-grained red granite, for the production of paving blocks. There are a great many large bowlders on the surface near by but only the solid ledges underneath are utilized. The stone fractures easily in the manufacture of pavers. Dimension stone could also be easily obtained. The total output to date is about 100,000 blocks.

Missouri Quarry.—There are several quarries now known under the name which were formerly called the Abbott openings. They lie at the end of a switch extending from Knob Lick, in the western part of section 17 (Tp. 34 N., R. VI E). Work was begun here several years ago but the quarries have not been developed to any extent except for the manufacture of paving blocks. However, since connections have been made with the Belmont railway the intention is to extend the works and put in equipment primarily for the production of dimension stone. Two large steam derricks are in position. There are two openings; the main one lies at the end of the switch, the other about 125 yards to the north. The latter is in red, rather coarsely crystalline granite, but the joints are hardly sufficiently numerous for easy working. The other is a small quarry now about twenty feet square and twelve feet deep. At

the large excavation the rock is of a grayish red color and very compact. In the southwestern part of the quarry there is a dike of fine-grained diabase traversing the granite in a nearly north and south direction. Its width is from twelve to eighteen inches and there are branches running off from the main mass. It is nearly vertical. About twenty car loads of grout have been taken away recently. The output thus far has been almost wholly paving blocks.

Chamberlain (J.) Quarry.—This is located on the section line between 17 and 18 (Tp. 34 N., R. VI E). It was opened in 1887 and is now about 150 feet one way by fifty feet in another, and seven feet deep. The stripping amounts usually to less than two feet and in places the hard undecomposed rocks extend to the surface. A quartz vein traverses the quarry in a direction south 65 degrees west. Along this intrusion the granite is very much jointed and of a gray color. There is a dike of diabase also crossing the granite of this quarry. It is the extension of the one shown in the Missouri quarry a short distance to the northeast. Since opened, probably 75,000 blocks have been gotten out. Large dimension stone might be obtained also.

Warsing Quarry.—This is a small opening in the northeast quarter of section 18 (Tp. 34 N., R. VI E). As yet it has been developed but little. The rock dresses easily and could be used advantageously for building stone. Up to 1894 only paving blocks had been taken out, of which about 10,000 had been marketed.

Fry Quarry.—Paving blocks were obtained until 1893 in the northwest quarter of section 18 (Tp. 34 N., R. VI E). The rock quarried was the ordinary reddish granite, rather coarse-grained and capable of being worked into blocks with comparatively little effort. Joint planes were not numerous, but sufficiently so to assist in quarrying. The output probably amounted to 10,000 blocks.

Kirkpatrick & Cross Quarry.—This small working lies southeast of the center of section 7 (Tp. 34 N., R. VI E). About 10,000 blocks were made from fine-grained red granite. Very

little solid rock was used, as large bowlders were most accessible.

Arnold Quarry is on Rock branch in the southwest quarter of section 7. It was opened seven or eight years ago, as were also others on the opposite side of the river at the "Narrows" in the northwest quarter of the same section (Tp. 34 N., R.VI E). Red granite of rather fine grain was worked with little difficulty. The rock is also adaptable to structural purposes. Full 75,000 blocks have been shipped from the several points.

In addition to the large number of quarries and "motions" at and in the vicinity of Syenite and Knob Lick, other localities have been found which would furnish a superior grade of granite and at some of these work could be prosecuted very successfully.

Four miles south of Knob Lick, on Musco creek, several quarries have been opened in the granite.

Carr Quarry.—This quarry lies in the southwest quarter of section 26 (Tp. 34 N., R. VI E). Work has been done on both sides of the creek at the railroad bridge. The stone quarried is a dark grayish rock, rather fine-grained. Joint planes are frequent. During the three years it has been in operation a large number of pavers has been taken out.

There is another quarry, but now abandoned, about one-half mile upstream from the Carr place, the old Kreitzer opening. This is on the west side of the gradually sloping granite hill. The blocks were hauled to Lewis switch a short distance westward. About three years ago the Bridgman quarries furnished paving blocks from red granite along the railroad near the center of section 22 of the same township and range.

Buck mountain is about two miles northwest of Skrainka and on its slopes to the northwest there are several quarries.

Hurst Quarry is located on the headwaters of Pine creek (Tp. 33 N., R. VI E., Sec. 32, NW. qr). Three or four openings have been worked and perhaps 25,000 blocks taken out.

Graham Quarry is near the Hurst and has been worked for paving blocks.

Billington Quarry. There were several excavations opened in the southwest quarter of section 30 (Tp. 34 N., R. VI E.) a few years ago and 25,000 paving blocks were produced. Operations have now ceased at this locality.

Vandergriff Quarry.—The two Vandergriff openings are close together and lie about half a mile north of the Billington. They were opened about the same time and 30,000 blocks made.

Lamb Quarry.—Openings have been made in half a dozen places in the northwest fourth of the southeast quarter of section 25 (Tp. 34 N., R. V E.), the principal one being the Lamb quarry. Only 15,000 blocks have been prepared, and the work has not been carried on continuously.

Lewis Quarry. Some work was done four years ago in several places in the vicinity of the Lamb place and 10,000 blocks manufactured. The rock is well adapted to block-making but is a little difficult to dress.

Phillips Quarry. Several small workings have been developed in the northeast fourth of the southeast quarter of section 25 (Tp. 34 N., R. V E.). They are known as the Phillips "motions." Reddish granite of rather coarse texture was quarried and 10,000 paving blocks sent out.

Bridgeman Quarry. There are several small excavations in the granite, located less than one-half mile south of the Phillips place. The rock is very similar in quality and color and about the same number of paving blocks have been made.

Martin Quarry. Four or five small quarries have been opened about one-half mile southwest of the Phillips. Work was carried on quite extensively for a time and the amount of the output was over 25,000 blocks.

The quarry industry was of considerable importance ten years ago in the area in which are situated the quarries in the southeast part of Tp. 34., R. V E., and in the southwest part of Tp. 34 N., R. VI E. The remoteness from railroad facilities militated against them. The granite is all of excellent quality and were transportation facilities nearer at hand work would doubtless continue.

Buck Mountain Quarries.—The work on Buck mountain has been confined principally to the southern end, in the northern part of section 5 (Tp. 33 N., R. VI E). Development began a dozen years ago. Later, much quarrying was undertaken and soon a large number of paving blocks were taken out and shipped. The rock has proved to be one of the best grades of granite in Missouri. From Syenite southward to the Buck Mountain area the quality is found to become better and better. The stone is easily dressed, receives a high polish and contains no deleterious constituents. A little quarrying is carried on here from time to time but extensive work has not been prosecuted for the past few years. Over 250,000 blocks were gotten out from the several openings.

Bald Mountain Quarries.—Bald mountain lies to the northwest of Skrainka. The first quarry was the Skrainka & Simpson, which was opened about eleven years ago. It is near the top of the mountain. Other quarrying has been done, mainly on the southwest flank, but no rock has been taken out here for nearly two years. There is but little stripping and the granite is of such a character as to make it a very desirable block stone. It fractures smoothly and wears well. The product was transferred on a long switch to the Belmont branch of the Iron Mountain railway.

Fredericktown Quarries.—In the vicinity of Fredericktown a number of openings have been made. About 300 yards north of the station east of the railroad track there is a small quarry. An excavation twenty feet square and twelve feet deep has been quarried out and worked into paving blocks. The rock is a fine-grained grayish pink stone, with easy fracture.

In the southeast quarter of section 6 (Tp. 33 N., R. VII E.) several small quarries have been opened up in a red granite; and from time to time the output of blocks is quite large. The blocks are of first-class quality and are easily made. At present no work is done in the locality.

In addition to the great number of quarries and "motions" in the granite, of which descriptions have already been given, there are numerous others which have been worked and which

have afforded a large number of paving blocks. Around Syenite and Knob Lick as far west as the eastern edge of section 5 (Tp. 34 N., R. VI W.) much quarrying has been done outside of the places particularly noted. They are perhaps not less important in extent, but not being in operation at the present time no definite information could be obtained regarding them. Many were filled with water and debris. The "blue" granite area, which lies between Knob Lick and Syenite has been worked into on the south as well as the north side of the road by many "motions" but none have taken out dimension stone, and work is now abandoned at the greater number of them. There are several "motions" in the granite near the center of section 3, west of Syenite.

QUARRIES IN PORPHYRY.

In those districts were there is a great abundance of granite, porphyry can never be quarried to advantage, principally for the reason that it is so difficult to work. For paving blocks, which at present form a very considerable part of the quarry output, porphyry is not popular. The blocks, aside from being difficult to make, become very smooth and slippery after being down a short time. Only one quarry of importance exists in the district.

Wells Quarry.—This is a "motion" near the top of Knob Lick mountain. Work in a compact porphyritic rock progressed for about a year, and 3000 pavers were made. The rock was found to be too hard for first-class blocks and was condemned. A few hundred porphyry blocks have also been taken out near this place but the work lasted only for a short time.

QUARRIES IN BLACK GRANITE.

The principal quarries of diabase are in the vicinity of Skrainka. The product is entirely paving blocks. The locality is about five miles northwest of Fredericktown (Tp. 33 N., R. VI E., Sec. 3). A dark green rock occurs here and is well exposed in a ravine at an abandoned quarry. It can be definitely traced almost to the divide to the eastward, southward for 100

yards or more, and northward for a greater distance. It is reported that the same rock was met with in a well one-fourth mile to the northeast. Branches from the main mass doubtless extend in various directions and although the exact connection has not been traced there are good evidences that some of them are either extensions of the principal one or else separate dikes. At several places along the headwaters of Frizelle branch (section 4) just west of Bald mountain, dike rocks are also very numerous. One and one-half miles south of Skrainka there are bowlders of the same rock. To all appearances there is no difference between the Skrainka diabase and that of neighboring localities.

A quarry at Skrainka was opened about eleven years ago and worked about two years as the Skrainka & Simpson quarry. Then for a season it was operated as the Simpson quarry; after which it became the LaMotte opening. For nearly six years no work has been done. At times as many as 150 men were employed in getting out stone and making blocks which were shipped over a switch to the Belmont branch railroad. The principal quarry is now about one hundred yards long by fifty yards wide. "Motions" were also opened. In the southern end of the quarry the rock has decomposed to a depth of thirty to forty feet and has left only a coarse sandy, brown colored mass, in which an occasional solid bowlder is present. Hard rock doubtless exists to the southward. On the other side of the opening the depth to hard diabase is only a few feet. It is estimated that nearly 200,000 blocks were made of this diabase. It works very easily and is gotten out with little difficulty, since joint planes are quite abundant. The supply of block stone is practically inexhaustible.

Large diabase bowlders are found in great numbers along the county road one and one-half miles south of Skrainka. They are not decomposed and many have been worked into paving blocks. The character of the stone is almost identical with that of the Skrainka diabase.

Near the north and south section line, on the southeast extension of Knob Lick mountain, about 100 feet below the sum-

mit, there are several small "motions" in green diabase. The stone is fine-grained, but makes a very good paver. It is not difficult to dress; and if it were found in greater abundance and more conveniently situated would doubtless be utilized much more extensively. For several years the excavations have been abandoned.

MARBLES.

The marbles, as found in the district under consideration, are very fine, close-grained, throughly crystalline stones which have every appearance of having been metamorphosed by heat. They have rather a limited areal distribution and are confined to a few small areas in the southwestern corner of the sheet. There is a great variety of colors, ranging from nearly white, to pale straw, gray, pink, through all the reds, to dark chocolate. The effects are very beautiful and in many cases the colors are variegated and exquisitely blended. All the varieties take a brilliant polish and are suitable for all kinds of ornamental work. Little effort has yet been made to develop the marble beds, as the chief drawback has been the lack of shipping facilities. At the present time the quarries are so far from the railroad that in order to get the stone to market it must be hauled over rough roads for distances of five to twelve miles. Enough however has been done notwithstanding the various drawbacks to show clearly the character, adaptability and extent of the beds in the localities. With the proper transportation facilities at hand the marbles could doubtless be made the source of considerable wealth.

QUARRIES IN MARBLE.

Allen & Smith Quarry.—Formerly the opening was known as the Covert, or Cedar Bottom, quarry. It is located about three miles south of Silver mines and ten miles southwest of Fredericktown (Tp. 33 N., R. V E., Sec. 25, SE. qr). It lies in the largest deposit in the district, covering about one square mile. Most of the area is of very gentle slope, but in spite of the low surface relief but little debris has collected over the

greater portion of the marble deposit, and in places the thickness of the residual clays barely cover the hard layers. In color and texture the stone varies greatly. Some ledges are flesh-colored; others the same but clouded with light streaks; others are of darker shades of red, either uniform or motled; while certain strata are of a very dark cherry red color. The texture is homogeneous. For the most part the stone has a compact, fine-grained matrix, through which are scattered small grains of more coarsely crystallized material either of marble or of pure calcite. Then there are thinner layers of semicrystalline rock of a uniform texture; others of either of those mentioned, with an occasional band more crystalline and sometimes thin broken streaks of dark red clayey material. The latter occurs in occasional layers and is not deleterious. The stone dresses readily. The ledges are from a few to twenty-four inches in thickness. Almost any desired sizes of blocks may be secured. Being the surface rock with little or no stripping and in a well-drained locality quarrying is carried on with almost no obstacle to intefere. The marble is hard and slightly brittle but takes a splendid polish and is suitable for monuments, mantles and ornamental work, and especially indoor trimmings and decorations.

Gale Quarry.—There are two small quarries on the Gale land, the principal one lying in the center of an old grant, corresponding to the south-central part of section 29 (Tp. 33 N., R. VI E.), and the other across the road about half a mile. There are about 160 acres of marble in the deposit. The openings were made fifteen years ago. A considerable amount of stone has been taken out for monuments and samples. The rock in the northern opening is exposed along a branch and in order to quarry it but little stripping is required. The principal ledge is eighteen inches in thickness, has a light grayish pink, clouded color and is quarried in large blocks. Earthy partings of greenish clayey material are occasionally shown, facilitating the getting out of the stone. The ledges are without joints except at wide intervals so that the stone in the ledge may be cut into thin slabs for indoor trimmings, man-

tles, steps and base-boards. The upper ledge is ten inches thick and of a pinkish gray color. The general texture is fine-grained. Both ledges admit of a fine polish. Small monuments have been prepared from the upper bed. Other layers exist but are not now worked. Only about one car load of these marbles has been shipped.

In the southern opening only the weathered ledges are shown. The most important layer is several inches thick. It is tolerably tough and takes a high polish.

Wright Quarry.—The Wright quarry is about a mile north-east of the Gale (Tp. 33 N., R. VI E., Sec. 28, NW. qr., S ½) in the side of a ravine. Work towards developing these ledges began about fifteen years ago and a number of blocks of the stone taken out, two or three car loads of rough stone being shipped from Fredericktown. No stripping of consequence is necessary to reach the best ledges which can be gotten out in slabs sixteen inches thick. As a rule the stone has a peculiar texture. It is rather dull, finely textured and granular in appearance, the latter character being well brought out in the polished faces. It is remarkably easily worked and not in the least "plucky." The color is commonly a very dark brick-red, approaching brown; in this general hue are blotches and specks of lighter color and of clear white calcite which give a striking as well as beautiful effect to the dressed stone.

Strong & Gillespie Quarry.—The opening in the marble just north of the main east and west road along the headwaters of Slater branch was formerly known as the Slater quarry but is now called the Strong & Gillespie. The quarry is on the south slope of the hill and considerably above the drainage level. A prospect shaft was sunk here through thirty or forty feet of marble and the formation was not passed through. A large amount of stone has been taken out from the quarry. Some has been shipped and some of it used for monuments. The stone is light to dark red in color, and partly banded with thin veins of white, the latter are of calcite and do not interfere with the solidity nor durability of the rock. The clayey seams which occasionally occur near the outer surfaces of the layers

are somewhat injurious in that they are sources of undesirable fractures and do not polish well. The thickness of the strata in sight ranges from a few inches to two feet and immense blocks are obtainable. A single large derrick has been employed.

LIMESTONE.

The limestone of the district comprise two principal varieties: dolomite, and ordinary limestone. Outside of the granite field they form a considerable belt along the northern, eastern and southern margins of the sheet.

Dolomite is the most important of the calcareous quarry-rocks and most of the limerocks are of this nature. Its stone is buff, compact, fine-grained, massively bedded. Often some silicious matter is present either in the form of fine quartz sand or chert.

On the Mine la Motte estate three analyses of the rock gave the following results:

Analyses of Dolomite.

	I	II.	III.
Calcium carbonate ($CaCO_3$)	52 10	51 21	49 29
Magnesium carbonate ($MgCO_3$)	43.92	45 89	31 63
Ferric oxide (Fe_2O_3)	2.79	2 32	7 81
Insoluable	1 19	1 22	10.32
Totals	100.00	100.63	99.10

One of the samples (I) was from Rock creek one mile east of the road crossing, north of the village. The second (II) is from the old lime kiln half a mile farther up the creek. The third (III) is from the eastern part of the estate.

Exposures of heavily bedded dolomite are of frequent occurrence. Outside of the granite area these outcroppings are usually so situated as to enable quarrying to be done without much expense on account of stripping. Quarrying in the magnesian limestones has been carried on in the area more or less extensively for a long time, but never has the work gone be-

yond satisfying local demands. It is not due, however, to the fact that there is not a great abundance of first-class building material, but rather to the fact that other districts within shipping distance are alos well supplied. The limestones are well adapted to foundation walls, sills, steps, bridge piers and all of the common uses.

Ordinary Limestone.—While there are some beds of limestone which contain very little magnesia they are comparatively few in number and extent. As quarry rocks they are unimportant within the district.

QUARRIES IN LIMESTONE.

Downs Quarry.—This quarry is about two miles northwest of Fredericktown (Tp. 33 N., R. VI E., Sec. 11, NE. ¼ of NW. qr). It is circular in shape. The stripping has a maximum thickness of four feet but usually only from three to fifteen inches. This covering is of residual clays and there is a decomposed limestone ledge present. The strata here dip with the floor of porphyry about 15 degrees, south 20 degrees east. The actual juncture is not distinctly shown, but crystalline rocks are exposed only a few feet up the hillside from the quarry. The same dip of strata is noticed for nearly half a mile to the southeast and is one of the best illustrations of the slant of the sedimentaries agreeing in places with the angle of the slope of the granite floor. The top ledge of limestone is from three to twelve inches in thickness. It thins out up the slope. It is of a light grayish color, is finely textured and of dull lustre. It is taken out in slabs containing eighteen square feet and is well adapted for curb stones, water tables and well rocks. Under the first layer comes a heavy ledge of very similar character but containing fewer grayish to buff horizontal seams. It is a good building stone but has not been extensively used. Much of the stone for the new college building at Fredericktown was taken from this quarry.

Berryman Quarry lies just east of Fredericktown on the south side of Saline creek. It was opened a number of years ago and the stone was used for burning into lime. The present

face is about twenty feet long and fifteen feet high with no stripping. The ledges are light gray, hard, with a subcrystalline texture and from three to nine inches thick. It is easily quarried and is a good stone for constructional purposes. Much of the stone obtained from this quarry has been utilized for foundations.

About one mile south of Fredericktown, on the south side of the river, there is a bluff of limestone nearly forty feet high at the top of which a quarry is being developed. The strata are overlain by three to four feet of residuary clays. The beds quarried are from three to eighteen inches in thickness; most of them above five inches. They are buff to gray in color, usually semicrystalline, and easily quarried. Large blocks are obtainable which are handled by means of a derrick.

In the vicinity of Mine la Motte a considerable amount of quarrying has been done in the limestone strata. The principal use has been as a flux in the furnace. Besides the ordinary demand for building stone has been satisfied. Some of the limestones have a composition well suited for a good flux. Along Rock creek nearly one mile east of the crossing of the north and south county road from Mine la Motte, limestone is now being taken out and hauled to the furnaces.

Other quarrying has been done in the dolomite formation especially to the east and south of Fredericktown and also near Libertyville. At both localities splendid ledges for building stone have been developed.

SANDSTONE.

The sandstones as a rule are yellowish or buff in color, changing into brown. They are rather friable on the whole, but in places are indurated sufficiently to form a moderately good quarry rock.

Although occupying a large area in the Mine la Motte sheet neither the sandstone nor the conglomerate at the base have receive much attention in the quarry industry. There are objectionable features to many of the beds; much of it is poor in color, others have a texture unsuited to successful dressing,

and still others are of shaly character. Unless a sandstone is of a high grade, limestone has preference in localities where both are present. There are really no important sandstone quarries in the district, although a large amount of sandstone has been used locally for foundations and chimney work. The more calcareous sandstones are to be preferred. Around Mine la Motte the heavy ledges of this kind have been quarried extensively and used as building stone.

About two and one-half miles almost due south of Doe Run there are two or three steep hills of sandstone. These are bare and disclose a good grade of sandstone which is hard enough for structural purposes. It may be obtained with almost no difficulty. It is however, quarried, pulverized and hauled to the furnace at Doe Run and thrown in with the lead just before it is drawn off, so as to "cinder" the product. The sandstone has been found to contain 97 per cent of silica, being unusually pure. It could doubtless be used in the manufacture of glass.

CHARACTER AND GROWTH OF THE QUARRY INDUSTRY.

The opening of the inexhaustible beds of rock suitable for building purposes forms one of the most important industries in the area of the Mine la Motte sheet; and within this district the quarry industry is destined to become greatly expanded. With the exception of a few localities, furnishing supplies of sandstone and limestone for local consumption, the quarry industry was of small importance until about the year 1880. At that time work began on a somewhat extensive scale, and now there are almost innumerable quarries of various sizes putting out all kinds and various grades of building material. The principal field of operation is in the vicinity of Knob Lick and Syenite, and in a district extending five to six miles in a southwesterly direction from these places. There are besides a great many insolated quarries, some of which are of considerable extent. In the neighborhood of the localities mentioned there were only a few small openings made in the granites prior to the date named and a little dimension work begun. About

that time two large quarries were opened at Syenite; and soon afterwards extensive quarrying commenced at Skrainka.

The importance and growth of the industry is shown by the output. The total product shipped from Knob Lick alone for the last fifteen years amounts to one thousand cars annually. This includes dimension stone, paving blocks, grout and spalls. There are now three principal quarries furnishing dimension stone. Two of these are equipped with steam power and polishing apparatus. Four or five of the works have switches or tramways extending from the quarry to the Belmont branch of the St. Louis, Iron Mountain and Southern railroad. Other short switches have been built from time to time.

Up to about 1890 there was an immense production of paving blocks, but within the last five years the annual output has decreased probably one-half. This decline was due to a number of circumstances. In the first place there was a great influx of quarrymen and as a result the number of blocks was greatly increased and in consequence the price was gradually lowered. For several years the blocks brought eighty dollars per thousand. A reduction was made to sixty-five dollars, then another to fifty, and finally during the the recent general commerical depression the cash value was only thirty-five dollars. The use of vitrified bricks and other materials for street-paving has tended to lessen somewhat the demand for the blocks. The late stagnation in business circles has also very materially effected the demand. However, the loss in the amount of blocks has to a great extent been compensated by a great increase in the amount of spalls utilized; for during the past five years a wide and constantly increasing use of this material in granitoid side-walks has more than made up for the deficiency in other directions. The first crusher was put in at Knob Lick four years ago, but it was subsequently transferred to St. Louis, and the rough grout shipped to that point. Spalls are worth about fifty cents a ton and the value is likely to increase as the supply of loose rock at the old quarries becomes exhausted; while the demand for the crushed rock is rapidly increasing.

Of course it is impossible at this time to secure anything like an accurate statement of the output of all the individual quarries. In the consideration of the various openings the production of many were given.

The total output from Knob Lick for the past fifteeen years has been probably 15,000 cars. For this period the average annual output of dimension rock has been about 150 cars.

The value of the block shipment approaches $500,000.00; that of the spalls and grout perhaps $25,000.00. The price of dimension stone is so variable that it is hard to estimate the average price of a car load. One monument alone may bring $1,000.00 or more.

The output of blocks from Skrainka and other quarries in the vicinity and westward and also along the railroad between Knob Lick and Fredericktown is estimated at 300,000, with a value of not less than $20,000.00. The shipments from Fredericktown have never been very great. Probably more than 100,000 blocks have been sent out; the valuation is in the neighborhood of $6,000.00.

CLAYS.

From an economical standpoint the clays occurring within the limits of the sheet cannot be considered as being of very great importance. There are several varieties of argillaceous materials including shale, ordinary residuary and transported deposits and kaolin. The shales are found between the heavy limestone ledges at varying depths and of thicknesses from a few inches to several feet. They are, however, inacessible and besides are too hard and calcareous to be of particular value. Decomposition of some porphyries and granites under certain conditions results in the formation of kaolin, very valuable deposits of which occur in the crystalline area of southeastern Missouri, but as yet none of consequence are known within the Mine la Motte sheet. The only clayey materials here which are in quantities sufficient to make them valuable are the com-

mon residual and alluvial deposits. The latter may either be free of injurious ingredients or may contain numerous pebbles and particles of stone, usually chert. These hard inclusions while not strictly deleterious interfere with the working of the material. In places the clays are from fifteen to twenty feet thick and homogeneous throughout. The character, or composition, depends primarily upon the nature of the rock from which the clay beds have been derived and secondarily upon the degree of completeness of original decomposition. Many of the limestones are overlain with a dark reddish brown clay. The chert hills are mantled with a cherty yellow clay, often quite thick. The granite, sandstones and porphyry clays are usually quite siliceous but adaptable to the manufacture of ordinary brick. The alluvial beds are usually too arenaceous for such purposes.

The distribution of the clays from which common structural brick can be made is quite general and from time to time a kiln or two of brick is burned first in one place, then another, just enough being made to satisfy the temporary local demands. At present only a single plant is putting out clay products. This is the Bonsor brickyard about one and one-half miles southeast of Fredericktown, near the Buckeye copper mines. It was opened in 1894 and one small kiln was burned. The green brick had been allowed to freeze and many of them were badly cracked, otherwise they were of good quality. The clay pit is on the level land at the foot of a hill and contains occasional chert fragments. From the cut the clay is wheeled to a Wallace disintegrator, crushed and conveyed by elevator to a Wallace stiff-mud machine and moulded into a side cut brick. Under careful treatment the material should afford a very good product.

LIME.

Although the accessible limestones are almost entirely dolomitic they are some of such composition that a fair grade of quick lime may be produced. It does not ordinarily burn well into what would be called a strong lime, but one suitable

for all kinds of mason work and for plaster. A small kiln is frequently burned in the various sections but the principal locality is along Rock creek about one mile northeast of Mine la Motte. Up to the present time the industry has not developed farther than to partially supply local demands.

SANDS.

The washed sands along the streams can be used in mortar and for all ordinary purposes but there are impurties in them which detract from their value. The sandstone hills a little more than two miles south of Doe Run, from which sand is secured for the furnaces at the mines, also furnish an abundance of material for many uses. It has been found to be ninety-seven percent silica, and as such could be used for the manufacture of glass, but the impurity is too great to produce first grades of white-glass, unless the foreign substances are removed. It is sharp, clean sand and a very superior grade for mortar and plasters. There is, however, no extensive demand for such material and the quarrying for the beds is mainly for the roasters at Doe Run.

MINERALS (not mined).

Besides the deposits which are being mined in commercial quantities and of which mention has been made, there are other minerals which have not as yet been mined. Some of these are found only sparingly, or in quantities too small to be of value as commercial products, yet possess considerable worth as mineralogical specimens, and as such frequently command good prices on account of their beauty, rarity, or peculiar scientific interest. Many minerals, particularly the metallic substances attract much popular attention, but occur in too limited amounts to pay for working them, yet they cause a great waste of time, energy and money in luring persons on with the hope of obtaining hidden wealth. Some minerals not now attracting attention may in the near future develop into sufficiently important deposits to attract capital.

SULPHIDES.

Galenite.—Galena, aside from being the principal lead ore of the region, also occurs in well defined crystals showing the cubic faces very slightly modified by the octohedron. In this form it is know as "cube" or "dice" mineral.

Sphalerite.—Although of very uncommon occurrence in southeast Missouri sphalerite has been reported from the Silver mines where it is associated in a quartz vein with pyrite and galenite.

Pyrite.—Iron pyrites is found abundantly in the lead mines where it occurs massive with the galena. It is very abundant at Mine la Motte, Doe Run and the Silver mines. Good crystals are also found at these localities. At the latter place it is sufficiently abundant to mine. A considerable quantity was taken out at the opening of the mine and now forms a large dump near the mouth of the shaft.

Pyrrhotite.—This form of iron sulphide was first reported by Leonhard from Mine la Motte, where it occurs massive with the galena, and contains nickel and cobalt.

Chalcopyrite.—Occurs abundantly in the lead mines, massive with the other ores, and also in more or less well defined crystals.

Linnæite—This common cobalt ore as found at Mine la Motte occurs massive. It contains usually some nickel and is associated with the iron and copper pyrites in the principal lead ore.

FLUORIDES.

Fluor Spar.—The principal locality is at the Silver mines. It is an abundant mineral in the vein stuff and occurs in small quantities also in the granite where metamorphosed. The color is a rich amethyst, graduating into the almost colorless varieties. Although thoroughly crystalline it does not preserve its crystallographic faces.

OXIDES.

Quartz.—Occurs abundantly in the form of a very pure sandstone; also in metalliferous veins cutting granite. In cry-

stals it is also of frequent occurrence; and in the granites, of which it forms the principal constituent in small irregular grains, it often has the crystallographic boundaries preserved.

Tungstite.—As a fine yellow powder coating wolframite crystals at the Silver mines.

Illmenite.—Common in certain dike rocks; but rare in others.

Magnetite is a common constituent of granite and diabase, in which it occurs in minute, well formed crystals of octahedral habit. It resists decomposition much longer than the other components of the crystalline rocks except quartz, and consequently is washed away with the latter. Owing to its high specific gravity it rapidly accumulates in small excavations, where the currents of water in the freshet runnels are less rapid, and forms pockets of "black sand." A part is magnetic but a considerable portion is not so, owing doubtless to the fact that it has changed to hematite or limonite. Some of it is probably titaniferous. It occurs throughout the crystalline area.

Hematite.—Occurs abundantly in massive deposits and in veins in the porphyries and granites.

Limonite.—Abundant in residuary deposits. Also occurs after pyrite.

Asbolite.—Black earthy cobalt oxide has been obtained at several places on the Mine la Motte estate, principally at the main shafts. It was also formerly obtained at the Old Copper mines in the southwestern corner of the tract. It usually contains nickel.

Wad.—The oxide of manganese occurs almost entirely in black earthy masses associated with copper and cobalt ores.

CARBONATES.

Calcite.—Found abundantly filling small crevices. In lining cavities the crystallographic faces are well formed. A large series of rhombohedrons and scalenohedrons have been observed.

Dolomite.—Abundant massive, but rather rare in crystals.

Cerussite.—Found at the Mine la Motte both massive and in fine clear crystals.

Malachite.—Abundant massive at the Old Copper mines on the Mine la Motte estate, and old Buckeye mines southeast of Fredericktown and elsewhere.

Azurite.—Sparingly at Buckeye mines.

PHOSPHATES AND ARSENATES.

Apatite.—Only as minute crystals in the crystalline rocks.

Annabergite.—The hydrous nickel arsenate is reported by Leonhard from Mine la Motte as occurring in small gobular particles of an apple green color, on chalcopyrite and galenite.

Plumbogummite.—Reported by Leonhard from Mine la Motte where it is found in small greenish globules, of waxy lustre, on crystals of cerussite on galena whose surface is corroded.

SULPHATES AND TUNGSTATES.

Anglesite.—Chiefly found in the lead mines. At Mine la Motte often occurs in good clear crystals with sharp edges.

Wolframite.—Said by Haworth to occur in the main vein at Silver mines in sufficient quantities to indicate that the deposit may be of economical importance.

SILICATES.

Orthoclase.—The principal feldspathic constituent of the granites. In the porphyritic facies there are large crystals.

Microcline.—In well bounded crystals in porphyritic granite.

Albite.—In the acid crystallines this mineral is the principal plagioclastic representative.

Bytownite.—One of the leading feldspars occurring in the diabases.

Labradorite.—An abundant constituent of the basic dike rocks.

Biotite.—In the crystallines in small plates and grains, especially at Silver mines, Syenite and Fredericktown.

Sericite.—Abundant at the Silver Mines.

Muscovite.—Found in vein stuffs and as a secondary product from feldspar.

Chlorite.—Abundant in weathered crystallines.

Zinnwaldite.—Found in small crystals from one to ten millemeters in size, at the Silver mines.

Hornblende.—Common as a constituent in the granite south of Syenite.

Topaz.—In minute grains at the Silver mines, where it occurs in the altered granite.

Zircon.—Very abundant in minute crystals usually imbedded in feldspar crystals in granite. Sometimes forms clusters around biotite.

Augite.—Abundant as an essential constituent of the diabase.

Olivine.—Common in grains in certain diabases.

Epidote.—Rather rare. In small grains, as a secondary product, from the basic dikes.

WATER AND WATER POWERS.

The waters of the district may be regarded as belonging to two classes, the surface and the mineral. With the former the area is well supplied. Two good streams with clear sparkling water flow south nearly across the sheet. Wells of moderate depth yield abundant and never failing supplies of wholesome water.

While there are a number of mineral springs in the district the best known are in the vicinity of Fredericktown. They are all chalybeate waters. One spring is situated about one mile east of the town, and at one time had a wide reputation. The other is White spring located about six miles south of Fredericktown. It is beautifully situated and with a little expense the place could be transformed into a attractive resort. The rate of flow is about sixty gallons a minute; the temperature of the water about 52 degrees, that of the air being 72 degrees. The results of the analysis of this water by Schweitzer is as follows:

Analysis of Water of White Spring.

	Grains in gallon.	Grams in litre
Silica (SiO_2)	0.8081	0.0130
Ferric oxide (Fe_2O_3)	0.2020	0.0050
Lime (CaO)	1.9959	0.0340
Magnesia (MgO)	0.7594	0.0130
Soda (Na_2O)	2.0081	0.0344
Chlorine (Cl)	0.0175	0.0003
Carbon dioxide (CO_2)	7.9428	0.1361
Water in combination (H_2O)	1.6246	0.0278
	15.3055	0.2655
Oxygen	0.0041	0.0001
Mineral matter	15.3084	0.2654
Fixed residue	9.9074	0.1696

Specific gravity = 1.0004 Trace of organic matter No K, no Li, no SO_4

UNITED AS FOLLOWS

	Grains in gallon
Silica (SiO_2)	0.8761
Ferrous bicarbonate ($FeH_2(CO_3)_2$)	0.6497
Calcium bicarbonate ($CaH_2(CO_3)_2$)	5.7448
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	2.7714
Sodium bicarbonate ($NaHCO_3$)	5.4084
Sodium chloride (NaCl)	0.0288
Mineral matter	15.4792
Oxygen for Fe O	0.0292

For water powers the St. Francois river has a sufficient fall and volume to supply considerable power. At the present time there is only one dam. This is at Silver mines, but is not now utilized. It is a substantial stone structure having a head of twenty-four feet. (See plate xiv.)

SOILS.

With the exception of very limited alluvial areas the soils of the region are all residuary. They are composed of the

DAM ON ST. FRANCOIS RIVER AT SILVER MINES.

materials which have been left from the disintegration and decomposition of the rocks in place. As a result the soils formed from the different rock masses each have physical properties and peculiarities not possessed by any others, and hence each is easily distinguished.

The decay of the porphyry is much less rapid than in the case of the other rocks and as a rule the resulting soil is not so thick. Usually the soil derived from the rock is light grayish brown in color, rather clayey and somewhat intractable.

Unlike the porphyry soils those of the granite areas are commonly more presistent over the rocks from which they have been derived. This may be accounted for in the main, by the lower angle of hill-slopes in the case of the granite formations. The disintegration as well as the decomposition of the coarser rocks is more rapid and the washing away of the decayed material is not so complete. On the rolling upland the thickness of the felspathic clays and the soils is often as much as six to eight feet. These beds are sandy and of light yellow to brown color except at the surface where modified by decomposed vegetation. Bowlders of granite are frequently scattered through the residual clays and sometimes interfere with tilling.

The soils of the sandstone areas are very arenaceous, light and loose and perhaps less fertile than those from the other rocks. They form large areas. When underlain by heavy clay deposits they become much more productive.

The fertility of the limestone soils is well known. The rich red to brown clayey beds, formed by the decomposition of the limestone strata, have proved exceptionally fertile. Where ever these are found, occur the most luxuriant plant growths. The lands are durable and easy of cultivation. The soils with the under clays of very similar character often extend to a depth of fifteen to twenty feet. The texture is of such a character that much moisture is held, to be given up gradually during long periods of dry weather. Most of the eastern part of the Farmington lowland has soils of this description.

The cherty limestone areas supply a deep red clay and but for the presence of numerous angular chert fragments the soils would be easily tillable. It is however quite productive.

The alluvial soils are, as has been stated, confined to the bottom lands along the St. Francois and the Little St. Francois rivers and occasional small areas adjacent to some of the other larger streams. Even along the rivers mentioned the areas are by no means continuous. Its position with reference to the watercourse is ever changing. The sources of the materials making up the alluvial deposits cannot ordinarily be determined, since they have been transported and mixed thoroughly by repeated working over by water. The soils are as a rule rather light, somewhat sandy, but fertile.

FORESTRY.

There is much valuable timber within the area of the Mine la Motte sheet. The principal woods from which good timber may be made are the white and black oaks and the common yellow pine. There are a number of other kinds which might be utilized but are of less common occurrence. Among these might be mentioned the black walnut, the black gum, and several varieties of oaks.

To a certain extent each geological formation has a characteristic timber growth. In different portions of the sheet these vary and inter-mix but it is often practicable to disclose the nature of the rocks underlying the surface by the character of the principal trees supported. The rich, moist, alluvial lands bear particular species, such as the sycamore, the black and the white walnuts, the sugar and white maple and the laurel oak. The limestone and chert areas have a variety of oaks, but more particularly the black, the red and the burr. The post oak is found abundant on the poorer lands and often is the prevailing species on the granite uplands. The small shell-bark hickory is here also abundant. The porphyries support numerous varieties but more especially the yellow pine and the white and post oaks. The principal pine trees are confined to the southwestern portions of the sheet. The hills just across

the river from the Silver Mines are covered with pines eighteen inches and over in diameter. Other hills are nearly equally productive of pine. The character of the forestry over the flats depends somewhat upon the thickness of the clay overlying the rock. The rich lowlands have a very flourishing timber growth but the dry highland bear small trees, mostly scrub, or post oak. There are a number of saw mills now getting out oak and pine lumber. The making of railroad ties is also of some importance.

The principal trees, most of which are suitable for lumber, are as follows:

1. Yellow pine, Pinus echinatus, Mill.
2. Red cedar, Juniperus virginiana, Linn.
3. White walnut, or butternut, Juglans cinerea, Linn.
4. Black walnut, Juglans nigra, Linn
5. Black hickory, Hicoria alba, (Linn).
6. Pignut hickory, Hicoria grabra, (Mill).
7. Big shellbark hickory, Hicoria laciniosa, (Michx).
8. White hickory, common shell-bark, Hicoria ovata, (Mill).
9. Cottonwood, Populus monilifera, Ait.
10. Black willow, Salix nigra, Marsh.
11. Blue beech, Carpinus caroliniana, Walt.
12. Iron-wood, Ostrya virginiana, (Mill).
13. Hazelnut, Corylus americana, Walt.
14. Red birch, Betula nigra, Linn.
15. Beech, Fagus atropunicea, (Marsh).
16. White oak, Quercus alba, Linn.
17. Laurel oak, Quercus imbricaria, Michx.
18. Burr oak, Quercus macrocarpa, Michx.
19. Post oak, Quercus minor, (Marsh).
20. Chinquapin oak, Quercus muhlenbergii, Engelm.
21. Black jack oak, Quercus nigra, Linn.
22. Pin oak, Quercus palustris, Du Rol.
23. Willow oak, Quercus phellas, Linn,
24. Swamp white oak, Quercus platanoides, (Lam).
25. Red oak, Quercus rubra, Linn.
26. Black oak, Quercus velutina, Lam.
27. Wahoo, or winged elm, Ulmus alata, Michx.
28. American, or white, elm, Ulmus americana, Linn.
29. Slippery elm, Ulmus pubescens, Walt.
30. Hackberry, Celtis occidentalis, Linn.
31. Mulberry, Morus rubra, Linn.
32. White popular, Liriodendron tulipifera, Linn.
33. Pawpaw, Asimina triloba, (Linn).
34. Sassafras, Sassafras sassafras, (Linn).
35. Witch hazel, Hamamelis virginiana, Linn.
36. Sycamore, Platanus occidentalis, Linn.
37. Service berry, Amelanchier canadensis, (Linn).
38. Wild cherry, Prunus serotina, Ehrh.
39. Red bud, Cercis canadensis, Linn.
40. Honey locust, Gleditschia triacanthus, Linn.
41. White maple, Acer saccharinum, Linn.

42. Sugar maple, Acer saccharaeum barbatum, (Michx).
43. Buckeye, Æsculus glabra, Willd
44. Buck-thorn, Rhamus caroliniana, Walt
45. Linden, Tilia americana, Linn.
46. Dogwood, Cornus alternifolia, Linn.
47. Black gum, Nyssa aquatica, Linn.
48. Persimmon, Diospyros virginiana, Linn.
50. Black haw, Viburnum prunifolium, Linn.

ACKNOWLEDGMENTS.

In addition to the special investigations into the geological features of the Mine la Motte district notes originally taken by different members of the regular corps for other purposes than those directly connected with the areal work have been fully drawn upon. The topography, under the direction of Mr. C. F. Marbut, was done in great part in the year 1892 by Mr. E. H. Lonsdale assisted by Mr. E. Theilman. Much regarding the crystallines has been complied from the lately issued petrographical report and the supplementary notes by Dr. E. Haworth. The information concerning the lead mines was obtained largely in connection with work for the general report on the lead and zinc deposits of the state recently published. Lately Mr. Lonsdale spent some time in St. Francois and Madison counties chiefly in looking up the building materials and the list of quarries is derived in great part from this source, as well as notes on other topics. Many citizens residing within the limits of the sheet have aided very materially, and fully appreciating the scope of the work, have not only freely given much valuable information but also time and attention.

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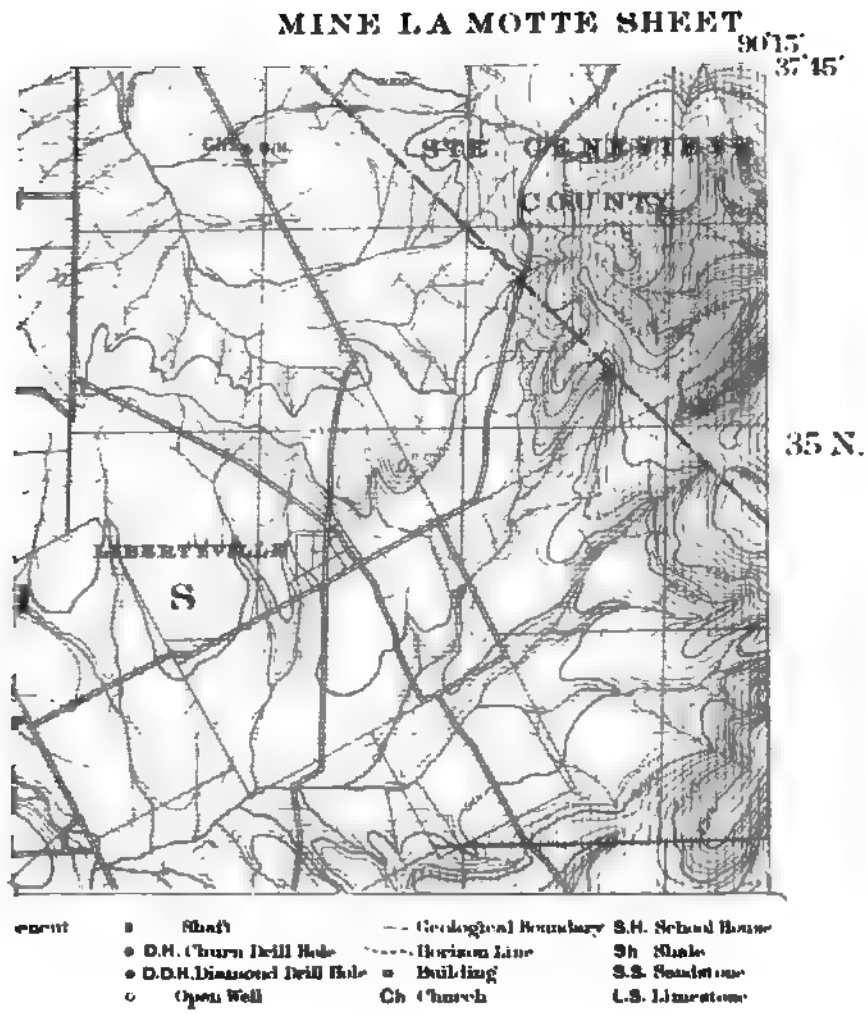
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L.S. Limestone

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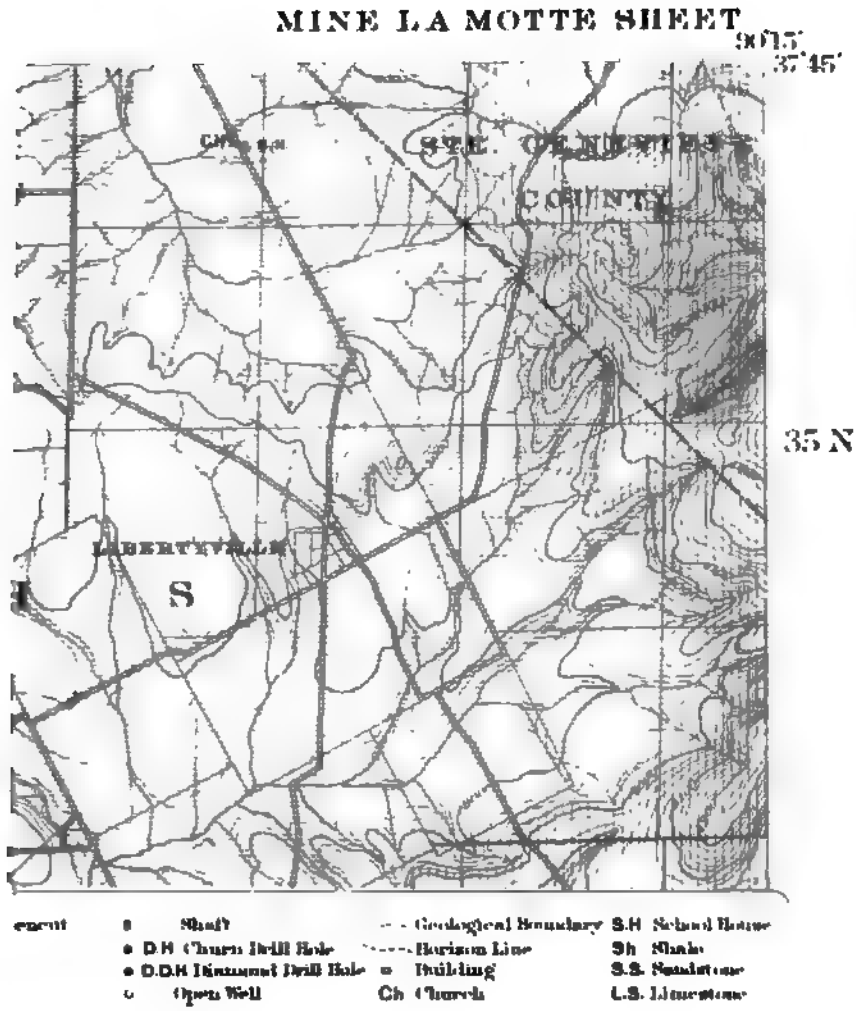
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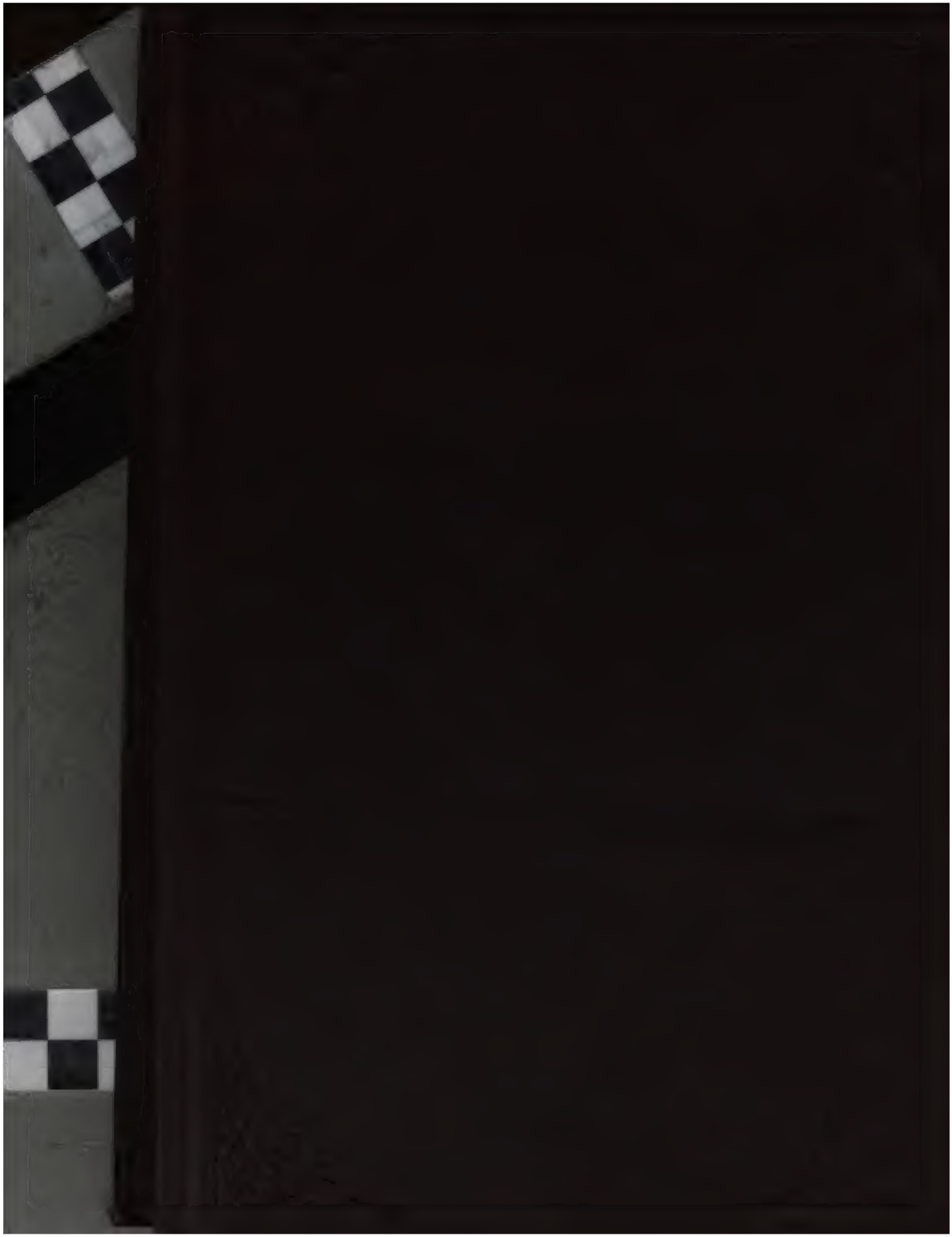
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